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010013 WO
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G06F 15/18, G06T 11/00

A1

(11) International Publication Number: WO 00/33207

(43) International Publication Date: 8 June 2000 (08.06.00)

(21) International Application Number: PCT/US99/28676

(22) International Filing Date: 3 December 1999 (03.12.99)

(30) Priority Data:

60/110,840	3 December 1998 (03.12.98)	US
60/112,391	15 December 1998 (15.12.98)	US
60/123,087	5 March 1999 (05.03.99)	US
09/440,317	12 November 1999 (12.11.99)	US

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(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

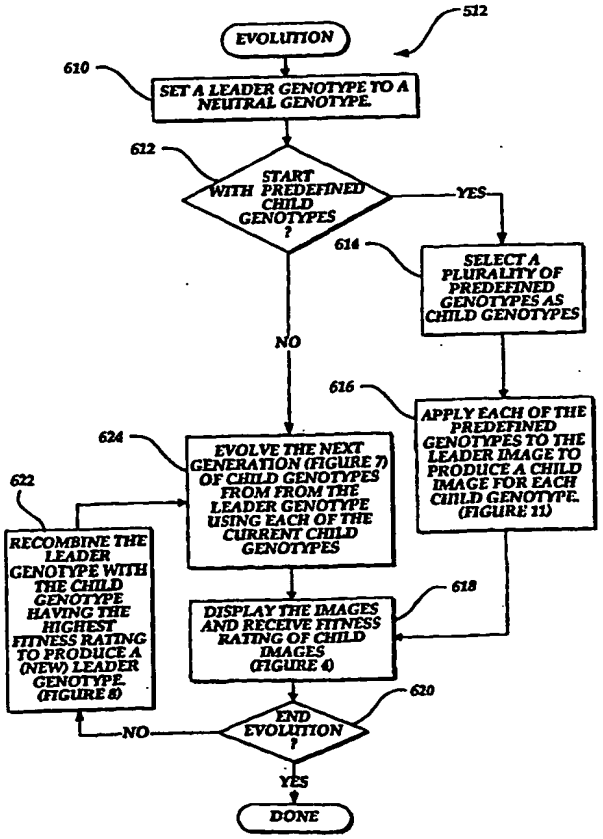
With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: DIGITAL IMAGE IMPROVEMENT THROUGH GENETIC IMAGE EVOLUTION

(57) Abstract

Computer–implemented methods and systems for improving a digital image using genetic algorithms is provided. Child images are evolved from the digital image using either predefined template genotypes or genotypes created through evolution. A genotype includes a number of genes that may each alter an attribute of the digital image such as hue, brightness, contrast or color saturation. The evolution includes a selection process during which the child images are compared against a leader image and assigned a fitness rating. The fitness rating is used in the evolution of subsequent generations of child genotypes, with each child genotype producing an associated child image. The evolution process may continue through as many generations as is desired and an improved image may be selected at any time during the evolution. Genotypes may be saved as independent data files and applied as template genotypes to other digital images. The methods and systems of the present invention also provide for evolving a printer calibration genotype that is used to adjust the image for the printing characteristics of a calibrated printer.



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DIGITAL IMAGE IMPROVEMENT THROUGH GENETIC IMAGE EVOLUTION

Field of the Invention

The present invention is in the field of computer applications and, more particularly, computer applications that improve the quality of digital images.

Background of the Invention

The growing popularity of digital photography and other digital images may be based in part on the ability to alter those digital images using computer programs. For instance, with editing tools currently on the market it is possible to selectively substitute one color in a digital image for another color, to change the size and shape of the digital image, to increase or decrease the brightness of the image, or to selectively correct the color saturation of an image so that colors appear more or less intense. While it is possible in theory to use these digital image editing tools to improve the overall quality of a digital image, in practice a high level of skill is required—the user must possess a fairly complete understanding of image attributes such as hue, brightness, color saturation, resolution, and gamma. Each change to a digital image requires an understanding of what to change, how to change it, and what effect the change may have on other attributes of the digital image. The user must expend considerable effort to alter the digital image to produce an acceptable image. If the user subjectively likes some of the changes made to the image, but not the final altered digital image as a whole, the effort expended on that final image may be completely lost. Conversely, if the user is satisfied with the final image, each of the changes must be remembered and manually repeated for similar images.

In some cases, a change made to one attribute of the digital image may unwittingly introduce unpleasant artifacts in the digital image. The methods of the prior art digital image editing tools often takes a "one size fits all" approach to editing attributes in the image. For instance, all color, contrast or brightness values in a digital image may be increased or decreased by a set value or according to a linear relationship such as $y = ax + b$. Prior art digital image editing tools, therefore, may only provide acceptable results to those that are skilled in color theory.

It would be desirable to have a digital image editing tool that is easily usable by a user from novice to expert to evolve a digital image so that it progressively becomes subjectively "better" in the eyes of a user. This digital image editing tool should be simple to operate, powerful in its ability to alter the digital image in beneficial ways, and efficient. The present invention is directed to providing such a digital imaging tool.

Summary of the Invention

In accordance with the present invention, computer-implemented methods and systems for enhancing a digital image are disclosed. Each image has an associated genotype, with the associated genotype having a plurality of genes. Each gene defines an attribute of the associated image such as brightness, color saturation, and contrast. The genotype may also contain genes that define methods for enhancing the digital image. For example, the gene may define a method for making a global color shift in the digital image or applying special effects to the digital image. The genotype may be a predefined template genotype or may be a genotype that is evolved through a selection process described below.

In accordance with the present invention, the selection process includes receiving a fitness rating for each of a plurality of digital images within a current generation of images. Each current generation of images generally includes a leader image and a plurality of child images. A copy of an original digital image is made the leader image of a first generation of images and the leader image is assigned a neutral leader genotype. A plurality of child genotypes are applied to the leader image with the application of each child genotype yielding a child image. After all the child images for the current generation have been created, the child images are sequentially compared to the leader image and a fitness rating is assigned to each child image. An improved image may be chosen at any time from any of the images in the current generation of images or the evolution can continue by making the current generation

of images a previous generation of images and evolving a next generation of images to become the current generation of images.

In accordance with other aspects of the present invention, the method of evolution creates a next generation of images by evolving a plurality of next generation child images from a next generation leader image. The next generation child images are created by applying a plurality of next generation child genotypes that are evolved from the leader and child genotypes of the previous generation of images. To create the next generation child genotypes, the leader genotype from the previous generation of images is recombined with a corresponding child genotype from the previous generation of images. The next generation child genotype is then mutated. A child image from the previous generation that received the highest fitness rating is made the next generation leader image. Each of the next generation child genotypes is applied to the next generation leader image to produce a next generation of child images. Since the next generation leader image and the next generation child images become the current generation of images for the selection process, the method of evolution in accordance with the present invention may continue through unlimited generations.

In accordance with other aspects of the invention, a genotype includes a plurality of genes. Each gene includes one or more parameters. The genotypes, genes and parameters are evolved through methods for recombination and mutation. In many cases, the parameters are used to interpolate one or more gradation curves for altering the leader image, i.e., each parameter value may have a different gradation curve that is interpolated between a boundary gradation curve and a neutral gradation curve ($y = x$). The boundary gradation curves (and thus the interpolated gradation curves) may be linear or non-linear and may be predefined or generated specifically for the digital image being processed. The gradation curve defines the replacement values for current values in the digital image when the gene is applied to the digital image. In other cases, the method of the gene directly changes the current values in the digital image.

In accordance with further aspects of the invention, any genotype may be stored independent of a digital image file and later applied to a digital image as a template genotype. The stored genotype comprises a relatively small data file that may be easily transmitted between computers across a communication network. Other template genotypes may be evolved by third parties or shipped with a product incorporating the present invention.

In accordance with yet further aspects of the invention, a printer calibration genotype may be provided as a template genotype or evolved according to a method and system of the present invention. The printer calibration genotype adjusts the digital image for the particular printing characteristics of the printer being calibrated. Before the digital image is sent to the printer, the printer calibration genotype is applied to the digital image.

Brief Description of the Drawings

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a block diagram of a general purpose computer system suitable for implementing the present invention;

FIGURE 2A is a block diagram illustrating a common storage method for storing a digital image file;

FIGURE 2B is an illustration of a color space model used by an actual embodiment of the present invention;

FIGURES 3A, 3B and 4 are pictorial representations of a user interface provided by an actual embodiment of the present invention;

FIGURE 5 is a functional flow diagram of a main processing loop, in accordance with the present invention;

FIGURE 6 is a functional flow diagram illustrating an evolution of a digital image, in accordance with the present invention;

FIGURE 7 is a functional flow diagram illustrating a process of creating a set of child images from a leader image using a method of genetic evolution, in accordance with the invention;

FIGURE 8 is a functional flow diagram illustrating a process for recombining genotypes, in accordance with the present invention;

FIGURE 9 is a functional flow diagram illustrating a process of recombining a leader genotype with a fitness-rated child genotype, in accordance with the present invention;

FIGURE 10A is a functional flow diagram illustrating the process of mutating a genotype, in accordance with the present invention;

FIGURE 10B is a mutation rate table containing values for mutation rates used in the process illustrated in FIGURE 10A;

FIGURE 11 is a functional flow diagrams illustrating the process of applying a genotype to a digital image, in accordance with the present invention;

FIGURES 12A-12C are a functional flow diagram illustrating the process for creating RGB gradation curves for gene 1 (global color shift) of the present invention;

FIGURES 12D-12E are graphs of boundary gradation curves used by the process illustrated in FIGURES 12A-12C, in accordance with the present invention;

FIGURE 12F is an illustration of interpolating an interpolated gradation curve between a boundary gradation curve and a neutral gradation curve;

FIGURE 13A is a functional flow diagram illustrating a process of providing the RGB gradation curves for gene 2 (color temperature) in accordance with the present invention;

FIGURES 13B-13D are graphs of boundary gradation curves used in the method illustrated in FIGURE 13A;

FIGURE 14 is a functional flow diagram illustrating a method for specifying the RGB gradation curves for gene 3 (effects), in accordance with the present invention;

FIGURE 15A is a functional flow diagram illustrating the method for determining a blackpoint and whitepoint gradation curve for gene 8 (blackpoint/whitepoint), in accordance with the present invention;

FIGURE 15B is a graph of an example blackpoint and whitepoint gradation curve;

FIGURE 16A is a functional flow diagram illustrating process of providing the RGB gradation curves for gene 4 (brightness), in accordance with the present invention;

FIGURES 16B-16C are graphs of boundary gradation curves referenced by the processes of FIGURES 16A and 18;

FIGURE 17 is a functional flow diagram illustrating the process of providing a contrast gradation curve for gene 5 (contrast), in accordance with the present invention;

FIGURE 18 is a functional flow diagram illustrating the process of adjusting a pixel's color saturation value using gene 6 (color saturation), in accordance with the present invention;

FIGURES 19A-19B are a functional flow diagram illustrating the method for adjusting the black level in primary colors using gene 7a (black level), in accordance with the present invention;

FIGURES 19C-19D illustrate curves referenced by the method of FIGURES 19A-19B;

FIGURES 20A-20C are a functional flow diagram illustrating the method for selective color correction of a pixel using gene 7b (selective color correction), in accordance with the present invention;

FIGURE 21A is a functional flow diagram illustrating a process for preparing a contrast gradation curve for gene 9 (contrast gradation curve), in accordance with the present invention;

FIGURES 21B and 21C are pictorial representations of a histogram and a gradation curve, respectively, calculated by the process illustrated in FIGURE 21A, in accordance with the present invention;

FIGURE 22 is a functional flow diagram of a process for removing optical distortion in digital images (dewarp), in accordance with the present invention; and

FIGURES 23A-23C are a functional flow diagram illustrating a process for calibrating a printer using a genetic algorithm, in accordance with the present invention.

Detailed Description of the Preferred Embodiment

FIGURE 1 illustrates a computer system 100 of conventional design that is suitable for practicing the present invention. The computer system includes a central processing unit (CPU) 110 that executes program instructions and manipulates digital data. The central processing unit 110 is coupled to a volatile memory 112 and a non-volatile memory 114 that store the program instructions and data. The central processing unit 110 is coupled to a video monitor 116, which provides a human recognizable medium for the display of digital images, text and other data to a user. A keyboard 119 and a pointer device 117 (a "mouse") are coupled to the CPU 110 for providing input to the computer 100. A printer 118 may be coupled to the CPU 100 to provide printouts of images, text and other data. The CPU 110 may also receive input from devices such as a digital camera 120 or optical scanner 122. Both the digital camera 120 and the optical scanner 122 record photographic images as computer-readable digital image files.

A plurality of computers 100 may be connected to a communication network 124 such as a local area network (LAN), a wide area network (WAN), or global network such as the Internet. For the ease of discussion below, it will be assumed that only a user computer 100 and a remote computer 126 are connected to

the communication network 124. A remote computer 126 is generally similar in configuration to that described for computer 100.

A digital image file 210 (FIGURE 2A), such as that created by the digital camera 120 or the optical scanner 122 (FIGURE 1), comprises data representing a plurality of pixels 212. When rendered on the video monitor 116 or the printer 118, the plurality of pixels visually form an image. In FIGURE 2A, the digital image file 210 is assumed to be 480 x 480 pixels in size. Of course, other digital image file sizes, formats and resolutions can be used when practicing the present invention.

An exemplary pixel 212 is shown in a partial view in FIGURE 2A. The pixel 212 is defined by a red (R) data value 214, a green (G) data value 216, and a blue (B) data value 218 (collectively the "RGB values"). Together, a red (R) data value 214, a green (G) data value 216, and a blue (B) data value 218 define a color for the pixel 212 from a set of colors available in a color space. A color space is a mathematical representation of a set of colors. In other words, by specifying an R value 214, a G value 216, and a B value 218, a color in the color space can be replicated for each pixel 212 on the video monitor 116, a printer 118, or other device.

A RGB color space is illustrated in FIGURE 2B as a hexagon 220, with each of the additive and subtractive primary colors indicated at a vertex. The primary colors red 222, green 224, and yellow 226 are known as the additive primary colors, and the primary colors magenta 228, cyan 230, and blue 232 are known as the subtractive primary colors. Using either of the additive primary colors 222, 224, 226 or the subtractive primary colors 228, 230, 232, any color within the color space can be specified. The number of colors that can be specified in the color space depends on the resolution of each RGB value 214, 216, and 218. The resolution is defined by the number of bits of data that are used to capture and store each of the RGB values--the more bits, the more colors that can be described In the following discussion, it will be assumed that the RGB values have a resolution of eight bits, or 256 possible values. Each pixel, therefore, can specify more than 1.6 million different colors in the RGB color space defined by hexagon 220. However, the resolution and size (number of pixels) in the digital image is not important to processes of the present invention. The digital image file 210 may have a resolution that is higher or lower depending on the quality requirements for the digital image, and practical matters such as storage requirements for the digital image file 210. Other color space models may be used without departing from the scope of the present invention. Examples of other color space encoding include YIQ, YUV,

YCbCr, HSI, and HSV. All of these color spaces can be translated to the RGB color space 220 described herein using well-known conversion methods.

The digital image file 210 may be stored in many different formats that are well known in the art. For instance, the RGB values 214, 216, 218 can be individually stored for each pixel in the digital image file 210 in a bitmap, or these RGB values may be translated, compressed and stored in a variety of other formats such as TIFF, JPEG, or MPEG, among other known digital image file 210 formats. All file formats may be processed by the present invention.

A user interface 300 provided by an actual embodiment of the present invention is illustrated in FIGURES 3A-3B and 4. In FIGURE 3A, the user interface 300 includes a menu bar 310 that contains menus named File 312, Edit 314, View 316, Window 318, Special 320, and Help 322. The File menu 312 includes a drop-down menu that includes items for saving and retrieving the digital image file 210 to and from the non-volatile memory 114, including options to Open, Open Special, Close, Save, Save As, and Save Genotype As. The Open Special option will be discussed further with reference to FIGURE 3B. A genotype may be saved in a separate data file using the Save Genotype As option in this menu (genotypes are discussed below beginning with the discussion of image evolution in FIGURE 5). The digital image file 210 may also be loaded into the application controlling the user interface 300 using file menu options to Acquire the image from a device such as scanner 122 (FIGURE 1) or from another device using a Select Source menu option. The image may be printed on the printer 118 using File menu options for Print, Print Preview (on the display), Printer Setup, and Printer Calibration. Printer calibration is described below with reference to FIGURE 26A-C. The user may also select an option for Preferences or may select an Exit option from the drop-down menu to end the application.

The Edit menu 314 includes options to Undo the Last Action, Perform a Dewarp on the Image, to Start Evolution, and to Rotate Left, Rotate Right, Resize Image, Crop Image, and to Remove Red Eyes. The Perform a Dewarp option is discussed below with reference to FIGURE 22 and the Start Evolution option is discussed below beginning with FIGURE 6.

The View menu 316 allows for the selection of user interface elements that the user wishes to appear in user interface 300. These user interface elements include a Toolbar menu item (toolbar 324), a Status Bar menu item (status bar 326), a Navigator window menu item (navigator 328), and Genotypes window menu item

(genotypes 330). The View menu 316 also provides the options to Compare to Original and to present the Optimal View of the image.

The Special menu 320 allows options to adjust the Color Temperature of the image (FIGURE 13A) and the Genotype Intensity (FIGURE 6). As will be better understood from the following discussion, this is accomplished by the use of a slider that goes from 0 % to 100 %. All genes are interpolated between their current value (= 100 %) and their neutral value (= 0 %). The Window and Help menus 318 and 322 offer menu items well known to those skilled in the art and will not be discussed further.

Referring to FIGURE 3A, the user interface 300 has an image display area 332 that displays a digital image file 210 that has been opened for enhancement. In the remainder of this discussion, the digital image file 210, as it exists when loaded into the present invention, will be referred to as a parent image 334. A miniature (thumbnail) version of the parent image 334 is displayed in a navigator 328 window. By using a slider control 336, a minus command button 338 or a plus command button 340, a user can select a percentage of the total image and only a portion of the parent image 334 will be displayed in the display area 332.

The genotypes list box 330 contains a list of template genotypes that may be applied to the parent image 334 to change the parent image 334 according to the predefined genes and gene parameters of the template genotype selected. For instance, if the inverse (INV) template genotype 335 is selected from the list box and an Apply command button 340 is activated, the INV template genotype 335 would be applied (FIGURE 11) to the parent image 334 and would result in an evolved image replacing the parent image in the display area 332. In the example shown, the evolved image would appear as a black background with a white outline of a sailboat. If a Reject control button 342 is activated, the parent image 334 will revert to the state it was in just before the INV template genotype 335 was applied.

The toolbar 324 includes command buttons for many of the functions described as menu items in the menus 310 described above. In particular, a Dewarp command button 344 activates the image Dewarp process illustrated in FIGURE 22, a color temperature button 346 adjusts the color temperature as illustrated in FIGURE 13A, an image cropping command button 348 activates a function for cropping the parent image 334, and a remove red eyes command button 350 activates a remove red eyes function.

The user interface presented when the Open Special method of the present invention available from the drop-down file menu is invoked as illustrated in FIGURE 3B. The Open Special user interface 360 includes a directory tree window 362 for selecting the directory 364 containing image data files which may be imported into the present invention. Each image 366A, 366B, 366C, 366D, 366E . . . stored in the directory 364 is displayed as a thumbnail image that, when selected (as indicated by a dark border surrounding the image), is opened for editing by the present invention by activating an Open button 368. A drop-down list box 370 lists available template genotypes. When an available template genotype is selected, selected thumbnail image (or images) are changed by the selected template genotype. When loaded, the loaded image is changed by the selected template genotype.

The present invention quickly and efficiently improves the quality of digital images through evolution. The evolution process is initiated by activating the Start Evolution command button 352 (FIGURE 3A). Referring to FIGURE 4, when the Start Evolution command button 352 is actuated, the image display area 332 changes to display a copy of the parent image 334 as a leader image 334A in the left-hand portion 417 of the image display area 332 and one of a set of four child images 334B, 334C, 334D, and 334E in the right-hand portion 415 of the image display area 332. Thumbnail images of the leader image 334A and of the four child images 334B-E are displayed in a legend area 410 together with an indication 412 of the generation to which the images 334A-E belong. Each child image 334B-E is sequentially displayed in the right-hand portion 415 of the image display area 332 for comparison with the leader image 334A that is displayed in the left-hand portion 417 of the image display area 332. The child image 334B is compared to the leader image 334A and fitness rated by selecting a portion of a graduated control 414. The graduated control 414 has a "no better or worse" portion 416 and a graduated portion 418 associated with values from 1% to 100% better. By using the pointer device 117 to select a portion of the graduated control 414, a fitness value equal to the percentage selected from the graduated control 414 (and displayed 419 below the graduated control 414) is associated with the child image 334B. Once a fitness value has been associated with the child image 334B, the next child image 334C is displayed in the right-hand portion 415 of the image display area 332 for comparison with the leader image 334A. The process of assigning a fitness rating for images 334D and 334E continues in the same manner just described. The status bar 326 displays an indication

of the current generation and the number of the child image 334B-E that is currently being compared.

At any point during the comparison process, the evolution can be stopped by activating a Stop Evolution command button 420. In response to activating the Stop Evolution command button 420, a user dialog is displayed asking whether the left image (leader image 334A) or the right image (child image 334B-E) should be kept. The kept image can then be saved as a new digital image file 210 or otherwise manipulated by the user's computer 100.

If the evolution of the image is allowed to continue, a next generation is evolved and a next generation leader image 422A is displayed in the right-hand portion 417 of the video display area 332. As is discussed below in more detail, the next generation leader image is created from a (new) leader genotype that is produced by recombining the (previous) leader genotype with the genotype of the highest fitness-rated child from the last generation. Four next generation child images 422B-E are evolved and displayed in the legend area 410 with an indication 412 that the second generation is being viewed. The child images 422B-E are then compared to the leader image using the graduated control 414 to assign fitness ratings as is discussed above.

It should be noted that what constitutes the "best" or "most fit" image (reflected by the value that is assigned to each image 334B-E, 422B-E, etc.) process is subjective and may differ among any two users because of the user's perception of color and personal preferences. The evolution process may be continued through any number of generations until the user finds the best image according to that user's subjective tastes. As will become apparent in the following discussion, the method of the present invention for very quickly evolving a "best" image (according to the individual tastes of the user) is based in part on the user's indication of a fitness rating of each of the child images 334B-E, 422B-E, etc.

The methods of the present invention for improving a parent image through evolution will now be discussed in detail beginning with FIGURE 5. A parent image is imported 510 from the non-volatile memory 114 (or other source such as the digital camera 120 or optical scanner 122) into a workspace available to the present invention in the volatile memory 112. When imported 510, the encoded information describing the parent image (e.g., in formats such as bitmap, JPEG, TIFF, etc.) is translated into equivalent red, green, and blue (RGB) values for each pixel 212 in the digital image 210. As will be understood by those skilled in the art, the translation of

the information describing the parent image into the RGB color space 220 is not absolutely necessary and the method of the present invention could be applied equally to many other color space models that are well known within the art.

Once the parent image is converted into pixels described by RGB values, the parent image can be modified according to the present invention by image evolution 512, applying a template genotype 514, or conducting an image Dewarp 516. Any digital image 210 can be accurately printed following a printer calibration 518 according to the method of the present invention. These four processes 512, 514, 516, 518 will be discussed below. Any or all of the above methods 512, 514, 516, 518 may be conducted in any order on a parent image until the program is exited 520.

If image evolution is selected 522, evolution is performed 512 beginning with the process illustrated in FIGURE 6. Referring to FIGURE 6, the evolution method 512 sets 610 a leader genotype to a neutral genotype. A genotype is a set of genes (described below) that are used to alter a digital image in a number of ways. A neutral genotype contains genes that do not affect the digital image to which they are applied. The evolution of the first generation of child images may be produced using predefined genotypes or evolved genotypes. If predefined genotypes are selected 612, then the method 512 selects a plurality of predefined template genotypes that are used as the initial child genotypes. Each child genotype is applied 616 to the leader image to produce a corresponding child image. The child images are displayed 618 and the method 512 receives the fitness ratings of each of the child images from the user (as was described above with reference to FIGURE 4).

If a request has not been received to end the evolution (e.g., by pressing the Stop Evolution command button 420), the evolution continues 620 by recombining 622 the genotype of the child image that received the highest fitness rating with the leader genotype as a next generation leader genotype. As is illustrated beginning in FIGURE 7, a next generation of child genotypes is evolved 624 using this next generation leader genotype. Alternatively, if the evolution is ended 620, the method 512 is done 626.

Referring to FIGURE 7, the evolve next generation method 710 begins by recombining 712 the leader genotype with a child genotype from the previous generation into a next generation child genotype. Recombination is discussed below with reference to FIGURE 8. The next generation child genotype is then mutated 714 in the manner illustrated in FIGURE 10 and described below. Having been

recombined and mutated, the next generation child genotype is applied 716 (FIGURE 11) to the currently loaded image (the leader image) to produce a next generation child image. The next generation child genotype is then associated with the next generation child image.

As discussed above, an actual embodiment of the present invention produces four child images in each generation for comparison with that generation's leader image. Of course, greater or fewer child images can be produced in each generation. For each child genotype from the previous generation, the evolve next generation method 710 repeats (starting with recombining 712 the child genotype with the leader genotype into a next generation child genotype). Once all child genotypes has been processed, a decision 720 directs the evolve next generation method 710 to return 722 all the next generation child images, together with their associated next generation child genotypes, as child images for presentation as a (new) current generation in the selection process described above (FIGURE 4). The method 710 is then done 724.

The method 810 for recombining the leader genotype with each child genotype to produce a plurality of next generation child genotypes is illustrated in FIGURE 8. The method 810 retrieves 812 a leader genotype. (It is to be understood that each of the methods described herein may retrieve, create or be passed data.) A child genotype is then retrieved 814. The individual genes of the leader genotype are recombined 816 with the genes of the child genotype into a next generation genotype, in the manner illustrated in FIGURE 9 and described below. If another child genotype is to be recombined, a decision 818 returns the method 810 to the retrieval 814 of another child genotype and the process is repeated. When all of the child genotypes have been recombined with the leader genotype, the next generation genotypes are returned 820 as the (new) child genotypes to block 712 in FIGURE 7. The method 810 is then done 822.

Referring to FIGURE 9, the method 910 of the present invention for recombining the leader genotype with a child genotype begins by retrieving 912 a leader gene from a set of genes contained in leader genotype. A corresponding child gene is also retrieved 912 from the child genotype. Each gene may contain one or more parameters which are retrieved 914 one at a time from the leader gene and then the corresponding child gene. A next generation gene parameter is computed 916 by taking a weighted average of the leader gene parameter and the child gene parameter. In this computation 916, the child gene parameter is weighted by a factor that equals

the fitness rating that was assigned to the child genotype (as discussed above with reference to FIGURE 4). For instance, if the resolution was eight bits (256 values), the weighting formula would be:

$$NextGenerationGeneParameter = \frac{LeaderGeneParameter + (FitnessRating * ChildGeneParameter)}{127}$$

This weighted average formula produces a next generation gene parameter that is stored 918 in a next generation gene. A decision 920 is made to determine if there is another gene parameter to process. If so, the method 910 returns to retrieve 914 the (next) leader gene parameter from the leader gene and a corresponding child gene parameter from the child gene. If all gene parameters have been processed, the decision 920 directs the method 910 to store 922 the next generation gene in the next generation genotype. If there is another leader gene to process, a decision 924 returns the process to the beginning of method 910 to retrieve 912 the next leader gene and a corresponding child gene. If the decision 924 determines that there is not another leader gene to process, then the method 910 is done 926.

The method 1010 for mutating a genotype is shown in FIGURE 10A. The method 1010 retrieves a genotype to be mutated from a block 714 in FIGURE 7. A gene from the genotype is retrieved 1012 and a mutation rate is obtained for the gene from a mutation rate table (FIGURE 10B). The mutation rate table provides the mutation rate to use for the gene being processed (column) and the number of the generation currently being processed (row). For instance, if gene 4 is being mutated from generation 5, cell 1016 would be selected to obtain a value of "18" hexadecimal. If the evolution has progressed through more than 16 generations, the mutation rate is selected from the generation 16 column according to the genes row. For instance, all mutations after the 16th generation for gene 5 will have a mutation rate found in cell 1018 that indicates a hexadecimal value of "1A".

Returning to FIGURE 10A, the mutation rate is multiplied 1022 by a Gauss-random value to produce a mutation value from a Gauss-random function. The Gauss-random function returns a value that makes small changes to the mutation rate very probable while big changes will seldom occur. Gauss-random functions are well known to those skilled in the art and will not be further discussed. The mutation value is then added to the gene to produce a mutated gene. If the gene has multiple parameters, all parameters are mutated. The mutated gene is then stored 1026 in a

mutated genotype. If another gene in the genotype needs to be processed, the method 1010 is directed 1028 to retrieve 1012 the next gene in the genotype. If another gene is not present in the genotype to be mutated, the method 1010 is directed 1030 to return 1032 the mutated genotype as the next generation genotype. The method 1010 is then done 1034.

The method 1110 for applying a genotype to a digital image is shown in FIGURE 11. The leader (currently loaded) image is retrieved 1112. The child genotype to be applied to the leader image is also retrieved 1114. A pixel is retrieved 1116 from the currently loaded image and a gene is retrieved 1118 from the genotype. The gene is applied 1120 to the pixel according to a method associated with each gene, as is discussed below in detail with reference to FIGURES 12A-21.

A decision 1122 determines if there is another gene in the genotype that still needs to be processed. If so, the method 1110 directs 1124 the retrieval 1118 of the next gene from the genotype. If there is not another gene in the genotype to be processed, the decision 1122 directs 1126 the method 1110 to store 1128 the newly altered pixel in a child image. A decision 1130 determines if there is another pixel in the currently loaded image that still needs to be processed, and directs 1132 the method 1110 to repeat starting with retrieving 1116 the next pixel from the currently loaded image. If there is not another pixel in the currently loaded image, the decision 1130 returns 1136 the child image and the associated genotype to the calling method. The method 1110 is then done 1138.

As mentioned above, FIGURES 12A-21 detail a set of nine genes in a genotype provided by an actual embodiment of the invention. Other genes may be added to the genotype and still be within the scope and spirit of the present invention. For instance, a gene could be developed to create artistic effects for the image using the methods and systems described below. While the order that the genes are applied does not have to be strictly defined, the genes below are discussed in the order that they are applied in an actual embodiment of the invention.

Many of the genes described below include methods for defining a new gradation curve for each of the R, G, and B values. The application of the gradation curves specified by these genes occurs in FIGURE 11. Using the value of the gene parameter, a gradation curve (e.g., FIGURE 12D) is generated. This generated gradation curve is then referenced to assign a new value (the y-coordinate) to the R 214, G 216, or B 218 value for each pixel in the digital image.

The gradation curves shown in the FIGURES are illustrated as continuous curves both to more clearly point out the concept of the present invention and to point out that the methods and systems of the present invention apply equally to digital images of all resolutions, e.g., a gradation curve may be applied to a digital image with 8-bit resolution equally as well as to a digital image with 32-bit resolution simply by calculating a greater range of data points for (or from) the gradation curve. In an actual embodiment of the invention, interpolating a gradation curve (FIGURE 12F) is actually computing a new value (y-coordinate) for each possible old value (x-coordinate). Since this discussion assumes an 8-bit resolution, 256 new values (y-coordinates) are calculated--one for each of the possible old values (256 possible values). In some circumstances it may be more efficient to calculate all of these new values at once and store the new values (y-coordinates) in a lookup table keyed by the old value (x-coordinate). In other circumstance it may be more efficient to calculate a single new value (y-coordinate) as needed. Unless described otherwise below, the new value (y-coordinate) is an interpolated value calculated between a predefined or dynamically calculated boundary curve and a neutral curve (y = x).

It should be noted that the predefined boundary gradation curves described for the use of the genes discussed herein have been determined empirically and may be changed as further experience dictates. The same is true for the predefined data points used by some genes to dynamically calculate boundary gradation curves.

In FIGURE 12F, an example of interpolating a gradation curve is illustrated including: a neutral gradation curve (y = x) 1202, an example of a positive boundary gradation curve 1204, and an interpolated gradation curve 1206. The interpolated gradation curve 1206 in this example represents a weight (or parameter) value of 89. If the gene is defined by an 8-bit signed integer, giving 127 possible positive values (and 127 possible positive interpolated gradation curves), the positive boundary gradation curve 1204 represents the maximum parameter value (127). A gradation curve for any positive parameter value may be interpolated in between the neutral gradation curve 1202 (y = x) and the positive boundary gradation curve 1204 by using a weighted interpolation formula to compute a new y-coordinate (ynew) for the interpolated gradation curve 1206 from the boundary gradation curve (yboundary) 1204 for each possible RGB value (x):

For each x (256 values):

$$ynew = \left[\frac{(yboundary - x) \cdot parameter}{127} \right] + x$$

The interpolated gradation curve 1206 therefore comprises 256 new values (ynew) that may be stored in any convenient data structure for use in the methods and systems described herein, such as the lookup table described above or each ynew point may be calculated as needed.

The global color shift of gene 1 is accomplished by calculating a gradation curve for each of the RGB values. Gene 1 has three parameters, with the first parameter specifying which two of the three RGB gradation curves will be interpolated. If the gene 1 first parameter is 1, new red and green gradation curves are interpolated and the blue gradation curve is assigned a neutral gradation curve 1202. When the first parameter of gene 1 is equal to 2, new green and blue gradation curves are created and the red gradation curve is assigned the neutral gradation curve 1202. If the first parameter of gene 1 is equal to 3, new red and blue gradation curves are calculated and the green gradation curve is assigned the neutral gradation curve 1202. The second and third parameters of gene 1 are specified by a signed 8-bit integer with a range of -128 to +127. A gradation curve is calculated for every possible value of parameter 2 (and 3) by calculating a weighted interpolation between a predefined boundary curve and the neutral curve.

Referring to FIGURE 12A, a method 1210 of gene 1 is illustrated to produce red, green and blue gradation curves for use in the global adjustment of color in the image. Two of these gradation curves are interpolated using the second and third parameters of gene 1. The remaining color is assigned the neutral gradation curve (y = x). If gene 1 of a leader genotype has a first parameter equal to one, a decision 1212 directs 1214 the process to a decision 1216 that checks if the second parameter is positive. If the second parameter is positive, the decision 1216 directs 1218 a method 1220 to use the second parameter of the leader genotype gene 1 as a weight value to interpolate a new red global color shift gradation curve between a positive global color shift boundary gradation curve (FIGURE 12D) and the neutral gradation curve 1202 (FIGURE 12F). Returning to decision 1216, if the leader genotype gene 1 has a second parameter that is negative, the method 1210 continues 1222 by using the leader genotype gene 1 second parameter as the weight value to interpolate a new red global color shift gradation curve 1224 between the

negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve 1202 (FIGURE 12F).

Following the interpolation of the new red global color shift gradation curve 1220 or 1224, a decision 1226 is made whether the third parameter of the leader genotype gene 1 is positive. If so, the third parameter of the leader genotype gene 1 is used as the weight value to interpolate a new green color shift gradation curve between the positive global color shift gradation curve (FIGURE 12D) and the neutral gradation curve 1202 (FIGURE 12F). If in the decision 1226 it is determined that the third parameter is not positive, the third parameter of the leader genotype gene 1 is used as the weight value to interpolate 1232 a new green global color shift gradation curve between the negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve (FIGURE 12F). A new blue gradation curve is assigned 1233 the neutral gradation curve (FIGURE 12F).

After the RGB gradation curves have been interpolated or assigned 1230, 1232 or 1233, or if the first parameter of the leader genotype gene 1 is not equal to one (decision 1212), the method 1210 continues as illustrated in FIGURE 12B. If gene 1 of a leader genotype has a first parameter equal to two, a decision 1234 directs 1236 the process to a decision 1238 that checks if the second parameter is positive. If the second parameter is positive, the decision 1238 directs 1240 the method 1210 to use the second parameter of the leader genotype gene 1 as a weight value to interpolate 1242 a new green global color shift gradation curve between the positive global color shift boundary gradation curve (FIGURE 12D) and the neutral gradation curve 1202 (FIGURE 12F). Returning to decision 1238, if the leader genotype gene 1 has a second parameter that is negative, the method 1210 continues 1244 by using the leader genotype gene 1 second parameter as the weight value to interpolate a new green global color shift gradation curve 1246 between the negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve (FIGURE 12F).

Following the interpolation of the new green global color shift gradation curve 1242 or 1246, a decision 1248 is made whether the third parameter of the leader genotype gene 1 is positive. If so, the third parameter of the leader genotype gene 1 is used as the weight value to interpolate a new blue color shift gradation curve 1252 between the positive global color shift gradation curve (FIGURE 12D) and the neutral gradation curve (FIGURE 12F). If in the decision 1248 it is determined that the third parameter is not positive, the third parameter of the leader

genotype gene 1 is used as the weight value to interpolate a new blue global color shift gradation curve 1256 between the negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve 1202 (FIGURE 12F). A new red gradation curve is assigned 1257 the neutral gradation curve 1202 (FIGURE 12F).

After the RGB gradation curves have been interpolated or assigned 1252, 1256 or 1257, or if the first parameter of the leader genotype gene 1 is not equal to two (decision 1234), the method 1210 continues as illustrated in FIGURE 12C. If gene 1 of a leader genotype has a first parameter equal to three, a decision 1260 directs 1262 the process to a decision 1264 that checks if the second parameter is positive. If the second parameter is positive, the decision 1264 directs 1265 the method 1210 to use the second parameter of the leader genotype gene 1 as a weight value to interpolate 1266 a new red global color shift gradation curve between the positive global color shift boundary gradation curve (FIGURE 12D) and the neutral gradation curve (FIGURE 12F). Returning to decision 1264, if the leader genotype gene 1 has a second parameter that is negative, the method 1210 continues by using the leader genotype gene 1 second parameter as the weight value to interpolate a new red global color shift gradation curve 1268 between the negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve (FIGURE 12F).

Following the interpolation of the new red global color shift gradation curve 1266 or 1268, a decision 1270 is made whether the third parameter of the leader genotype gene 1 is positive. If so, the third parameter of the leader genotype gene 1 is used as the weight value to interpolate a new blue color shift gradation curve 1274 between the positive global color shift gradation curve (FIGURE 12D) and the neutral gradation curve (FIGURE 12F). If in the decision 1270 it is determined that the third parameter is not positive, the third parameter of the leader genotype gene 1 is used as the weight value to interpolate a new blue global color shift gradation curve 1278 between the negative global color shift gradation curve (FIGURE 12E) and the neutral gradation curve (FIGURE 12F). A new green gradation curve is assigned 1279 the neutral gradation curve (FIGURE 12F).

Gene 2 adjusts the color temperature of the child image 334B-E. Color temperature may be thought of as simulating a "warmer" or "colder" ambient light in the digital image. Gene 2 has a single parameter defined by a signed 8-bit integer (values from -128 to +127). Altered by gene 2, a negative parameter value result in the image looking warmer (lower color temperature caused by a shift toward orange-

red in the image) and a positive parameter will make the image look colder (higher color temperature caused by a shift toward blue in the image).

The method for calculating the RGB gradation curves 1310 to adjust the color temperature of an image is shown in FIGURE 13A. In an actual embodiment of the invention, a single new value (y-coordinates) is calculated for each of the RGB gradation curves, as needed, to adjust a single pixel instead of calculating and storing all of the new values (y-coordinates) of an interpolated gradation curve. However, the following will continue to refer to these new values as being part of a gradation curve to better illustrate the concept behind the method 1310 of gene 2.

The parameter value of gene 2 is used as a weight value to interpolate 1312 a red color temperature gradation curve ("RTemp") 1312 between a low temperature red boundary gradation curve (FIGURE 13B) and the neutral gradation curve (FIGURE 12F). Next, a green color temperature gradation curve ("GTemp") is interpolated 1314 using the gene 2 parameter as the weight value in a weighted interpolation between a low temperature green boundary gradation curve (FIGURE 13C) and the neutral gradation curve (FIGURE 12F). Finally, a blue color temperature gradation curve ("BTemp") is interpolated 1316 by using the gene 2 parameter as the weight value in a weighted interpolation between a low temperature blue boundary gradation curve (FIGURE 13D) and the neutral gradation curve (FIGURE 12F).

A decision 1318 determines if the gene 2 parameter is positive and directs the method 1310 to find 1320 a new low temperature RGB value (y-coordinate) corresponding to the old RGB value (x-coordinate) from each of the RGB low temperature gradation curves 1312, 1314, 1316, i.e.:

$$R = RTemp[x]$$
$$G = GTemp[x]$$
$$B = BTemp[x]$$

If the decision 1318 determines that the gene 2 parameter is not positive, the new RGB values are obtained 1322 from a set of high temperature RGB gradation curves that mirror the low temperature RGB gradation curves about the neutral gradation curve. The high temperature RGB gradation curves may be expressed mathematically as:

$$R = x - (RTemp[x] - x)$$
$$G = x - (GTemp[x] - x)$$
$$B = x - (BTemp[x] - x)$$

Alternatively, the high-temperature RGB boundary gradation curves may be defined separately from the low-temperature boundary gradation curves and the high-temperature RGB gradation curves interpolated between those separately defined high-temperature RGB gradation curves and the neutral gradation curve (FIGURE 12F). The new RGB values obtained in blocks 1320 or 1322 are then returned 1324 as a new pixel for the child image.

Gene 3 provides RGB gradation curves that define special effects. A method 1410 of gene 2 is illustrated in FIGURE 14. Gene 3 has three parameters that specify a gradation curve for each red, green, and blue value. The first parameter specifies 1412 a predefined gradation curve defining an effect to the red component of each pixel. For example, a predefined effect gradation curve could provide an inverse for the red value by having the equation $y = 255 - x$. The second parameter of gene 3 specifies 1414 a predefined effect gradation curve that defines an effect to the green component of the pixel. A third parameter specifies 1416 a predefined effect gradation curve that defines an effect to the blue value of each pixel. Depending on the effect desired, the first, second and third parameters may each specify the same gradation curve or a different gradation curve for each of the red, green and blue values. The method 1410 is then done 1418.

Gene 8 determines a blackpoint and whitepoint gradation curve that is applied to each of the RGB values. The method 1510 of gene 8 is shown in FIGURE 15A, where the brightest color tone in the image is assigned 1512 as the whitepoint and then the darkest color tone in the image is assigned 1514 as the blackpoint. Using the coordinates (0, whitepoint and 255, blackpoint) a linear gradation curve is computed 1516 between these coordinates. The method 1510 of gene 8 is then done 1518. An example of the gradation curve produced by gene 8 is shown in FIGURE 15B with the linear gradation curve 1520 extending between the blackpoint 1522 and the whitepoint 1524.

The RGB gradation curves calculated by gene 4 affect the brightness of the image. Gene 4 has one parameter that is a signed 8-bit integer, ranging from -128 (maximum brightness) to +127 (minimum brightness). In an actual embodiment of the invention, the same calculated brightness gradation curve is used for all the RGB values. The method 1610 for calculating the brightness gradation curve of gene 4 is shown in FIGURE 16A and begins with a decision 1612 that determines whether the value of the gene 4 parameter is positive. If yes, a brightness gradation curve is interpolated 1614 by using the value of a gene 4 parameter as the weight value in a

weighted interpolation between a positive brightness/color saturation boundary curve (FIGURE 16B) and the neutral gradation curve (FIGURE 12F). If the decision 1612 determines that the value of the gene 4 parameter is not positive, the weighted interpolation is made using the gene 4 parameter as the weight value between a negative brightness/color saturation boundary gradation curve (FIGURE 16C) and the neutral gradation curve (FIGURE 12F). After calculating the brightness gradation curve 1614 or 1616, the method 1610 is done 1618.

The contrast gradation curve produced by gene 5 is applied equally to each of the RGB values to alter contrast as the red, green and blue gradation curve for contrast. Gene 5 has one parameter that is a signed 8-bit integer ranging from -128 (lowest contrast) to +127 (maximum contrast). The method 1710 for finding the contrast gradation curve of gene 5 begins by retrieving 1712 the contrast parameter of gene 5. The contrast parameter is used as the weight value to interpolate 1714 a new contrast gradation curve between a boundary gradation curve generated by gene 9 (discussed below with reference to FIGURE 21) and a neutral gradation curve (FIGURE 12F). Next, a new contrast value is determined directly from the new contrast gradation curve 1716 for each of the RGB values of the pixel. The method 1710 is then done 1718.

The method 1810 for adjusting the color saturation of the image using gene 6 is illustrated in FIGURE 18. Gene 6 has a single parameter that comprises a signed 8-bit integer in an actual embodiment of the invention. The RGB values of the pixel being passed to method 1810 are each translated 1814 from their additive primary color values to the equivalent subtractive primary colors using the formulas:

C (cyan) = 255 - R (red)
M (magenta) =255 - G (green)
Y (yellow) = 255 - B (blue)]

The black level (K) is assigned 1816 the minimum value of the C, M or Y:

$$K = \min(C,M,Y)$$

This black level (K) is then temporarily removed 1818 from the subtractive primary colors using the formulas:

c (cyan) = C-K
m (magenta) = M-K
y (yellow) = Y-K

The subtractive primary colors are adjusted 1820 (FIGURE 11) using the Positive Boundary Brightness/Color Saturation Gradation Curves illustrated in FIGURES 16B and 16C (discussed above), weighted by the parameter of this gene. The black level (K) is then added back 1822 into the subtractive primary colors:

C = c+K
M = m+K
Y = y+K

The subtractive primary color values are translated back 1824 to their equivalent additive primary colors using the formulas:

R = 255 - C
G = 255 - M
B = 255 - Y

The method 1810 then returns 1826 the new pixel for storage in the adjusted image and is done 1830.

The method 1910 of gene 7A for adjusting the black level in the primary colors of the image is illustrated in FIGURES 19A and 19B beginning with the method 1910 retrieving 1912 the RGB values of a pixel. The RGB values are translated 1914 from the additive primary color values to the equivalent subtractive primary colors using the formulas:

C (cyan) = 255 - R (red)
M (magenta) = 255 - G (green)
Y (yellow) = 255 - B (blue)

The black level is determined 1916 to be the minimum value of the three subtractive primary values C, M & Y, which is otherwise expressed as:

$$K = \min(C,M,Y)$$

The black level is temporarily removed 1918 from the C, M & K values using the formulas:

c (cyan) = C-K
m (magenta) = M-K
y (yellow) = Y-K

and an intermediate color separation is made 1920 for each of the primary colors:

b' (blue) =min(c,m)
r' (red) =min(m,y)
g' (green) =min(c,y)
c' (cyan) =c-(g'+b')
m' (magenta) =m-(r'+b')
y' (yellow) =y-(r'+g')

Using the intermediate color separation values (b', r', g', c', m', y') as the x-coordinate, a Color Separation Graduation Curve (FIGURE 19C; "Curve1") is applied 1922 to each of the intermediate color separation values:

b7(blue) =Curve1[b']
r7(red) =Curve1[r']
g7(green) =Curve1[g']
c7(cyan) =Curve1[c']
m7(magenta) =Curve1[m']
y7(yellow) = Curve1[y']

Each intermediate separation value is adjusted 1924 by applying a corresponding gene parameter from gene 7A. Unlike other genes that are directly evolved during the evolution process described above, the parameters of gene 7A are changed by a regulator gene (gr) that is evolved during the evolution process. The regulator gene (gr) is set by the evolution process, i.e., by mutation and recombination. In an actual embodiment of the invention, the six gene parameters of

gene 7A have the values that are calculated using a predefined weighting factor to adjust the value of the regulator gene, i.e.:

$$g1 = 0.7 * gr$$
$$g2 = 0.15 * gr$$
$$g3 = 0.11 * gr$$
$$g4 = 0.078 * gr$$
$$g5 = 0.94 * gr$$
$$g6 = 0.94 * gr$$

The weight values used in g1-g6 have been determined empirically and may be changed as experience dictates. In choosing the weight values, however, it should be considered that the reduction in the black value of color should not be equal for all colors or unpleasant artifacts may result. It has been found that green, blue and cyan are the most robust against these artifacts and may be weighted more heavily, while red and yellow are the least robust against manipulation and should have smaller weight values. Using the six gene parameters of gene 7A, the intermediate color separation values are adjusted 1924 using the following formulas:

$$b7\ (blue) = (b7^* g1)/127$$
$$r7\ (red) = (r7^* g2)/127$$
$$g7\ (green) = (g7^* g3)/127$$
$$c7\ (cyan) = (c7^* g4)/127$$
$$m7\ (magenta) = (m7^* g5)/127$$
$$y7\ (yellow) = (y7^* g6)/127$$

The method 1910 next determines 1926 a black level correction factor (kf) from a predefined curve shown in FIGURE 19D (the "kfCurve"):

$$kf = kfCurve\ [K]$$

and a black level correction value is calculated 1928 for each primary color using the formulas:

$$c'' = kf^* c7/256$$

m"= kf*m7/256
y"= kf*y7/256
r"= kf*r7/256
g"= kf*g7/256
b"= kf*b7/256

Each of the intermediate color separation values is then enhanced 1930 with the black level correction values using the formulas:

c'=c'+c"
m'=m'+m"
y'=y'+y'
r'=r'+r"
g'=g'+g"
b'=b'+b"

Black is enhanced 1932 in accordance with the formula:

K = K -c" - m" - y" - r" -g" - b"

Finally, the black enhanced RGB values for a new pixel are calculated 1934 using the formulas:

C = c'+b'+g' + K
M = m'+r'+b' +K
Y = y'+r'+g' + K

R = 255-C
G = 255-M
B = 255-Y

and the new black enhanced RGB values are returned 1936 as an altered pixel for the child image. The method 1910 is then done 1938.

The method 2010 for the selective color correction of the image by gene 7B is illustrated in FIGURES 20A-C. The pixel passed to the method 2010 is separated

2012 into the pixel's RGB values, which are translated 2014 to the equivalent subtractive primary colors, using the formulas:

C (cyan) = 255 - R (red)
M (magenta) = 255 - G (green)
Y (yellow) = 255 - B (blue)]

and the black level (K) is determined 2016 from the minimum of the C M & Y values. This black level is temporarily removed 2018 from the subtractive primary colors using the formulas:

c (cyan) = C-K
m (magenta) = M-K
y (yellow) = Y-K

and an intermediate color separation is found 2020 as follows:

b' (blue) =min(c,m)
r' (red) =min(m,y)
g' (green) =min(c,y)
c' (cyan) =c-(g'+b')
m' (magenta) =m-(r'+b')
y' (yellow) =y-(r'+g')

The method 2010 then retrieves the eighteen parameters of gene 7B which are stored as unsigned 8-bit integers for each color except black: an amplification factor for the color being processed, an amplification factor for the clockwise adjacent color on the color hexagon 220 (FIGURE 2B) to the color being processed, and an amplification factor for the counterclockwise adjacent color on the color hexagon 220 (FIGURE 2B) to the color being processed.

Using a spline algorithm, eighteen gradation curves (3 for each color except black) are computed 2024 using the points: (0,0), (xpoint, ypoint), (255,255), where ypoint is equal to xpoint if xpoint is less than 230 or ypoint is equal to 230 if xpoint is greater than 230. Using 230 as the breakpoint has been determined empirically and may change as further experience dictates. The resulting 18 gradation curves are:

BBCorr[]	BlueCorrection for Blue
BCCorr[]	CyanCorrection for Blue
BMCorr[]	MagentaCorrection for Blue
MMCorr[]	Magenta Correction for Magenta
MBCorr[]	BlueCorrection for Magenta
MRCorr[]	RedCorrection for Magenta
RRCorr[]	RedCorrection for Red
RMCorr[]	MagentaCorrection for Red
RYCorr[]	YellowCorrection for Red
YYCorr[]	YellowCorrection for Yellow
YRCorr[]	RedCorrection for Yellow
YGCorr[]	GreenCorrection for Yellow
GGCorr[]	GreenCorrection for Green
GYCorr[]	YellowCorrection for Green
GCCorr[]	CyanCorrection for Green
CCCorr[]	CyanCorrection for Cyan
CGCorr[]	GreenCorrection for Cyan
CBCorr[]	BlueCorrection for Cyan

Using a the corresponding gradation curve listed above, the primary colors are selectively corrected 2028, as follows:

b'= BBCorr[b']
c'=BCCorr[b']
m'=BMCorr[b']

m' = MMCorr[m']
b' = MBCorr[m']
r' = MRCorr[m']

r' = RRCorr[r']
m' = RMCorr[r']
y' = RYCorr[r']

y' = YYCorr[y']
r' = YRCorr[y']
g' = YGCorr[y']

g' = GGCorr[g']
y' = GYCorr[g']
c' = GCCorr[g']

c' = CCCorr[c']
g' = CGCorr[c']
b' = CBCorr[c']

and then these selectively corrected colors are converted 2030 to their new RGB values and returned to the calling function as a new pixel for a child image using these formulas:

R=r'+m'+y'+K
G=g'+c'+y'+K
B=b'+c'+m'+K

The method 2110 of gene 9 provides the contrast gradation boundary curve that is used by the method 1710 of gene 5 (FIGURE 17). Referring to FIGURE 21A, the contrast gradation boundary curve is calculated by first converting 2112 each pixel into gray according to a gray scale. A histogram is then created 2114 that records the gray tone value of every pixel in the image with the x-axis of the histogram representing the gray scale value and the y-axis of the histogram representing the frequency that that gray tone appears in the image. An example of such a histogram 2130 is illustrated in FIGURE 21B. The histogram is integrated from its minimum value until 2% of the data members in the histogram has been reached. The value of the x-axis at this point is recorded 2116, as a first parameter (A) of gene 9. Similarly, the histogram is integrated from its maximum value toward its minimum value until 2% of the total data members has been reached. The value of the x-axis at

this point is recorded 2118 as a second parameter (B) of gene 9. The integration percentage (2%) was determined empirically and may be changed as experience dictates.

Using a spline interpolation, a S-shaped contrast gradation curve 2132 is calculated 2120 using (0,0) and (255,255) as the end points 2134, 2140 and the points (A, 12) and (B, 242) as the inflection points 2136, 2138. An example of this S-shaped contrast gradation curve with the end points and inflection points 2136, 2138 just described is illustrated in FIGURE 21C. Since, spline interpolation algorithms are well known in the art, they will not be discussed further here.

Returning to FIGURE 5, it is also possible to apply 514 a template genotype to the image without going through the evolution process. The template genotype may be predefined and shipped as part of the product incorporating the invention or may be a genotype that has been saved from a previous evolution. For example, a user may prefer a genotype that the user has evolved for photographs of mountains that the user wishes to apply to all pictures of mountains that the user works on. By saving the favored genotype as a template genotype, the genotype may be selected 524 and the genotype applied 514 to the image as was discussed above with reference to FIGURE 11. As mentioned above, any saved or template genotype forms a relatively small data file. This data file may be exchanged between applications employing the present invention, for instance, by sending the genotype data file from the user's computer 100 over the communication network 124 to another user's remote computer 126 (FIGURE 1).

The present invention also provides the option 526 to Dewarp the image. Performing 516 a Dewarp is illustrated in FIGURE 22. When taking a photograph through a lens, the not perfect shape of the lens may introduce a perceptible aberration in the image. The process of "Dewarping" an image minimizes the effect of this spherical aberration by redistributing the pixels in the image. The method 2210 of Dewarping the image begins by retrieving 2212 a predefined set of correction coefficients A, B, C. A focal point is then determined 2214 in the parent image. For each pixel in the parent image, the pixel is retrieved 2216 and a vectored radius between the location of the pixel and the focal point is determined 2218. A new vectored radius for the pixel is determined 2220 using the formula rnew=ar+b*r^3+c*r^5. The pixel is then stored 2222 in a child image at the new vectored radius (rnew). To make the image look more smooth, a bi-cubic interpolation is used. If there is another pixel to process in the parent image, a

decision 2224 returns control to the retrieval 2216 of the next pixel and the method continues as described above. If there is not another pixel to process in the parent image, the decision directs the method 2210 to end 2226.

The last option shown in FIGURE 5 is to select 528 printer calibration. A printer calibration is performed 518 according to the method shown in FIGURES 23A-C. Printer calibrations are necessary because the image produced by any given printer 118 may appear different than the image as it is displayed on the video monitor 116. With the present invention, a genotype may be developed that is associated with the printer and that is used to harmonize the image printed by the printer 118 with the image displayed on the video monitor 116.

The printer calibration method 2310 begins by retrieving 2312 a gray scale image. A gray scale template genotype is applied 2314 to the gray scale image to create a test image. The gray scale template genotype has genes that are neutral for all attributes other than brightness (altered by gene 4) and contrast (altered by gene 5). A decision 2316 determines if another gray scale test image should be produced. If yes, a different gray scale template genotype is applied 2314 to the gray scale image to create another gray scale test image. In an actual embodiment of the invention, five gray scale test images are produced. Each of the gray scale test images is displayed 2318 on the video monitor 116. The same gray scale test images are then printed 2320 on the printer 118 to be calibrated. The test images should be arranged on the printed page as they are displayed on the display so that the user may intuitively select 2322 the "best" test image appearing on the printed test page. (The "best" test image is a subjective determination by the user.) The genotype of the image is assigned as a printer gray scale genotype.

A red-dominant test image containing subject matter with many red tones is retrieved 2324. The printer gray scale genotype is applied 2326 to the red-dominant test image (as is described above with reference to FIGURE 11) to create a gray scale adjusted test image. A red-dominant template genotype is applied 2328 to the gray scale adjusted test image to create a red-dominant test image. If another red-dominant test image is desired, a decision 2330 returns control to the block 2328 to apply a different red-dominant template genotype to the gray scale adjusted test image to produce another red-dominant test image. When all the red-dominant test images are created, the decision 2330 directs control to the retrieval 2332 of a green-dominant test image. The printer gray scale genotype is applied 2334 to the green-dominant test image to create a gray scale adjusted test image. As above, a set of

green-dominant template genotypes are applied 2336 to the gray scale adjusted test image to create a set of green-dominant test images. A decision 2338 returns control to the block 2336 until all green-dominant test images have been produced.

The process is next repeated for a blue-dominant test image that is retrieved 2340 and adjusted by applying 2342 the printer gray scale genotype to the blue-dominant test image to create a gray scale adjusted test image. A set of blue-dominant genotypes are applied 2344 to create a set of blue-dominant test images using the control loop provided by decision 2346. When all the blue-dominant test images have been produced, the decision 2346 directs control to the display 2348 of each of the red-dominant, green-dominant, and blue-dominant test images on the video monitor 116. Each of the red-dominant, green-dominant and blue-dominant test images are printed 2350 on a test page by the printer 118. The test images should be arranged as they are displayed on the display so that the user can intuitively select the images from the printed page on the video display.

The user chooses 2352 a "best" red-dominant test image that appears on the printed test page and selects the corresponding red-dominant test image on the video monitor 116. This selects the genotype of the selected test image as the printer red-dominant genotype. Next, the user chooses 2354 the "best" green-dominant test image that appears on the printed test page and selects the corresponding green-dominant test image on the display. This assigns the genotype of the selected test image as the printer green-dominant genotype. The user then chooses 2356 the "best" blue-dominant test image that appears on the printed test page and selects the corresponding blue-dominant test image on the display. The genotype of the selected test image is assigned as the printer blue-dominant genotype.

Using the method illustrated in FIGURE 8, the printer gray scale genotype, the printer red-dominant genotype, the printer green-dominant genotype, and the printer blue-dominant genotype are recombined 2358 to form a printer calibration genotype that is stored as a printer calibration template genotype and associated with the printer 118 being calibrated. When the printer 118 is next used by the present invention, the image to be printed can be modified using the printer calibration genotype as it is sent to the printer to be printed so that the image printed matches the image displayed as closely as possible. The printer calibration method is then done 2360.

While the preferred embodiment of the invention has been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and scope of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A computer-implemented method of improving a digital image, the method comprising:

(a) displaying a digital image and designating the digital image a leader image;

(b) applying a child genotype to the leader image to produce a child image;

(c) displaying the leader image and the child image so that a user can select which of the child image and the leader image is more desirable; and

(d) repeating (b) and (c) for a plurality of child genotypes.

2. The computer-implemented method of Claim 1, wherein the child genotypes applied to the leader image are next generation child genotypes and the child images are next generation child images.

3. The computer-implemented method of Claim 2, wherein the next generation child genotypes are evolved prior to being applied to the leader image to produce next generation child images.

4. The computer-implemented method of Claim 3, wherein the leader image has an associated leader genotype and wherein evolving the next generation child genotypes comprises recombining the leader genotype with a child genotype.

5. The computer-implemented method of Claim 4, wherein evolving the next generation child genotypes also comprises mutating the recombined leader and child genotypes prior to the evolved next generation child genotypes being applied to the leader image to produce a next generation child image.

6. The computer-implemented method of Claim 5, wherein mutating the recombined leader and child genotypes comprises:

(a) selecting a gene from the genotype;

(b) determining a mutation rate for the gene;

(c) using a random value to adjust the mutation rate;

(d) applying the value of the adjusted mutation rate to the gene to produce a mutated gene;

(e) storing the mutated gene in a mutated genotype; and

(f) repeating (a) through (e) for all genes in the genotype.

7. The computer-implemented method of Claim 4, wherein recombining the leader genotype with a child genotype to evoke a next generation genotype comprises:

(a) retrieving a leader gene from the leader genotype and a corresponding child gene from the child genotype;

(b) retrieving a leader gene parameter from the leader gene and a corresponding leader gene parameter from the child gene;

(c) producing a next generation gene parameter by computing a weighted average of the leader gene parameter and the child gene parameter;

(d) storing the next generation gene parameter in a next generation gene;

(e) repeating (b), (c), and (d) for all parameters included in the retrieved leader gene;

(f) storing the resulting next generation gene in the next generation child genotype; and

(g) repeating (a) through (f) for all genes in the leader genotype.

8. The computer-implemented method of Claim 7, wherein evolving the next generation child genotypes also comprises mutating the recombined leader and child genotypes prior to the evolved next generation child genotypes being applied to the leader image to produce a next generation child image.

9. The computer-implemented method of Claim 8, wherein mutating the recombined leader and child genotypes comprises:

(a) selecting a gene from the genotype;

(b) determining a mutation rate for the gene;

(c) using a random value to adjust the mutation rate;

(d) applying the value of the adjusted mutation rate to the gene to produce a mutated gene;

(e) storing the mutated gene in a mutated genotype; and

(f) repeating (a) through (e) for all genes in the genotype.

10. The computer-implemented method claimed in Claim 1, including storing a fitness value assigned to a child image by a user for each child image displayed with a leader image for a user to select which of the child image and the leader image is more desirable.

11. The computer-implemented method of Claim 10 wherein the child genotypes applied to the leader image are next generation child genotypes and the child images are next generation child images.

12. The computer-implemented method of Claim 11, wherein the next generation child genotypes are evolved prior to being applied to the leader image to produce next generation child images.

13. The computer-implemented method of Claim 12, wherein the leader image has an associated leader genotype and wherein evolving the next generation child genotypes comprises recombining the leader genotype with a child genotype.

14. The computer-implemented method of Claim 13, wherein evolving the next generation child genotypes also comprises mutating the recombined leader and child genotypes prior to the evolved next generation child genotypes being applied to the leader image to produce a next generation child image.

15. The computer-implemented method of Claim 14, wherein mutating the recombined leader and child genotypes comprises:

(a) selecting a gene from the genotype;

(b) determining a mutation rate for the gene;

(c) using a random value to adjust the mutation rate;

(d) applying the value of the adjusted mutation rate to the gene to produce a mutated gene;

(e) storing the mutated gene in a mutated genotype; and

(f) repeating (a) through (e) for all genes in the genotype.

16. The computer-implemented method of Claim 13, wherein recombining the leader genotype with a child genotype to evolve a next generation genotype comprises:

(a) retrieving a leader gene from the leader genotype and a corresponding child gene from the child genotype;

(b) retrieving a leader gene parameter from the leader gene and a corresponding leader gene parameter from the child gene;

(c) producing a next generation gene parameter by computing a weighted average of the leader gene parameter and the child gene parameter, the weighting factor being based on the fitness value assigned to the child image associated with the child genotype;

(d) storing the next generation gene parameter in a next generation gene;

(e) repeating (b), (c), and (d) for all parameters included in the retrieved leader gene;

(f) storing the resulting next generation gene in the next generation child genotype; and

(g) repeating (a) through (f) for all genes included in the leader genotype.

17. The computer-implemented method of Claim 16, wherein evolving the next generation child genotypes also comprises mutating the recombined leader and child genotypes prior to the evolved next generation child genotypes being applied to the leader image to produce a next generation child image.

18. The computer-implemented method of Claim 17, wherein mutating the recombined leader and child genotypes comprises:

(a) selecting a gene from the genotype;

(b) determining a mutation rate for the gene;

(c) using a random value to adjust the mutation rate;

(d) applying the value of the adjusted mutation rate to the gene to produce a mutated gene;

(e) storing the mutated gene in a mutated genotype; and

(f) repeating (a) through (e) for all genes in the genotype.

19. The computer-implemented method of Claim 1, wherein the child genotypes include at least one gene for altering an attribute of the leader image when a child genotype is applied to the leader image to produce a child image.

20. The computer-implemented method of Claim 19, wherein the child genotypes include a global color shift gene for altering the global color of the leader image.

21. The computer-implemented method of Claim 19, wherein the child genotypes include a color temperature gene for altering the color temperature of the leader image.

22. The computer-implemented method of Claim 19, wherein the child genotypes include a special effects gene for altering the leader image by introducing special effects into the leader image.

23. The computer-implemented method of Claim 19, wherein the child genotypes include a blackpoint and whitepoint gene for altering the blackpoint and whitepoint of the leader image.

24. The computer-implemented method of Claim 19, wherein the child genotypes include a brightness gene for altering the brightness of the leader image.

25. The computer-implemented method of Claim 19, wherein the child genotypes include a contrast gene for altering the contrast of the leader image.

26. The computer-implemented method of Claim 19, wherein the child genotypes include a color saturation gene for altering the color saturation of the leader image.

27. The computer-implemented method of Claim 19, wherein the child genotypes include a black level adjustment gene for altering the black level of the leader image.

28. The computer-implemented method of Claim 19, wherein the child genotypes include a selective color correction gene for selectively correcting the colors of the leader image.

29. The computer-implemented method of Claim 1, wherein applying a child genotype to the leader image to produce a child image comprises:

obtaining a pixel from the leader image;

obtaining a gene from the child genotype;

applying the gene to the pixel to produce a modified pixel; and
storing the modified pixel in the child image.

30. The computer-implemented method of Claim 29, wherein applying the gene to the pixel to produce a modified pixel comprises:
obtaining a parameter from the gene;
using the parameter as a weighting value to interpolate a gradation curve between a boundary gradation curve associated with the gene and a neutral gradation curve;
obtaining a color value from the pixel;
determining a new color value (y-coordinate) from the gradation curve by using the color value as the lookup value (x-coordinate);
assigning the new color value to the modified pixel; and
returning the modified pixel for inclusion in the child image.

31. The computer-implemented method of Claim 30, wherein the boundary gradation curve is chosen based on a second parameter of the gene.

32. The computer-implemented method of Claim 30, wherein the color value comprises a plurality of color component values and each of the color component values is modified by applying a gradation curve only if specified by another parameter of the gene.

33. The computer-implemented method of Claim 30, wherein the boundary gradation curve is created by a support gene based on attributes of the image.

34. The computer-implemented method of Claim 30, wherein the parameter of the gene is regulated by a regulator gene.

35. The computer-implemented method of Claim 34, wherein the regulator gene is weighted by a weighting value, the color value comprises a plurality of color component values, and the weighting value is associated with a color component value.

36. The computer-implemented method of Claim 1, wherein the child genotype is a predefined template genotype.

37. The computer-implemented method of Claim 1, further comprising:

evolving a printer calibration genotype; and

applying the printer calibration genotype to an image before it is printed by a printer.

38. The computer-implemented method of Claim 37, wherein evolving a printer calibration genotype comprises:

applying a plurality of genotypes to a digital image, the application of each genotype producing a test image;

displaying each test image;

printing each test image on a printed test page using the printer;

receiving a selection of a best fit test image; and

assigning as the printer calibration genotype the genotype that produced the best fit test image.

39. The computer-implemented method of Claim 38, wherein evolving the printer calibration genotype includes determining the most fit gray scale genotype by:

applying a plurality of gray-scale genotypes to a gray-scale dominant digital image to produce a plurality of gray scale dominant test images, each gray scale genotype having an associated gray scale genotype;

displaying the gray scale dominant test images;

printing the gray scale dominant test images on a printed test page using the printer;

receiving a selection of the most fit gray scale dominant test image; and

assigning the associated gray scale genotype of the most fit gray scale dominant test image as the printer gray scale genotype.

40. The computer-implemented method of Claim 39, wherein evolving the printer calibration genotype also includes determining the most fit red-dominant scale genotype by:

applying the printer gray scale genotype to a red-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of red-dominant genotypes to a red-dominant digital image to produce a plurality of red-dominant test images, each red-dominant genotype having an associated red-dominant genotype;

displaying the red-dominant test images;

printing the red-dominant test images on a printed test page using the printer;

receiving a selection of the most fit red-dominant test image; and

assigning the associated red-dominant genotype of the most fit red-dominant test image as the printer gray scale genotype.

41. The computer-implemented method of Claim 40, wherein evolving the printer calibration genotype also includes determining the most fit green-dominant scale genotype by:

applying the printer gray scale genotype to a green-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of green-dominant genotypes to a green-dominant digital image to produce a plurality of green-dominant test images, each green-dominant genotype having an associated green-dominant genotype;

displaying the green-dominant test images;

printing the green-dominant images on a printed test page using the printer;

receiving a selection of the most fit green-dominant test image; and

assigning the associated green-dominant genotype of the most fit green-dominant test image as the printer gray scale genotype.

42. The computer-implemented method of Claim 40, wherein evolving the printer calibration genotype also includes determining the most fit blue-dominant scale genotype by:

applying the printer gray scale genotype to a blue-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of blue-dominant genotypes to a blue-dominant digital image to produce a plurality of blue-dominant test images, each blue-dominant genotype having an associated blue-dominant genotype;

displaying the blue-dominant test images on the video display;

printing the blue-dominant test images on a printed test page using the printer;

receiving a selection of the most fit blue dominant test image; and

assigning the associated blue-dominant genotype of the most fit blue-dominant test image as the printer gray scale genotype.

43. The computer-implemented method of Claim 42, wherein evolving the printer combination genotype also includes recombining the printer gray scale genotype, the printer red-dominant genotype, the printer green-dominant genotype, and the printer blue-dominant genotype to form the printer calibration genotype.

44. The computer-implemented method of Claim 38, wherein evolving the printer calibration genotype also includes determining the most fit red-dominant scale genotype by:

applying the printer gray scale genotype to a red-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of red-dominant genotypes to a red-dominant digital image to produce a plurality of red-dominant test images, each red-dominant genotype having an associated red-dominant genotype;

displaying the red-dominant test images;

printing the red-dominant test images on a printed test page using the printer;

receiving a selection of the most fit red-dominant test image; and

assigning the associated red-dominant genotype of the most fit red-dominant test image as the printer gray scale genotype.

45. The computer-implemented method of Claim 38, wherein evolving the printer calibration genotype also includes determining the most fit green-dominant scale genotype by:

applying the printer gray scale genotype to a green-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of green-dominant genotypes to a green-dominant digital image to produce a plurality of green-dominant test images, each green-dominant genotype having an associated green-dominant genotype;

displaying the green-dominant test images;

printing the green-dominant images on a printed test page using the printer;

receiving a selection of the most fit green-dominant test image; and

assigning the associated green-dominant genotype of the most fit green-dominant test image as the printer gray scale genotype.

46. The computer-implemented method of Claim 38, wherein evolving the printer calibration genotype also includes determining the most fit blue-dominant scale genotype by:

applying the printer gray scale genotype to a blue-dominant digital image to produce a gray scale adjusted test image;

applying a plurality of blue-dominant genotypes to a blue-dominant digital image to produce a plurality of blue-dominant test images, each blue-dominant genotype having an associated blue-dominant genotype;

displaying the blue-dominant test images on the video display;

printing the blue-dominant test images on a printed test page using the printer;

receiving a selection of the most fit blue dominant test image; and

assigning the associated blue-dominant genotype of the most fit blue-dominant test image as the printer gray scale genotype.

47. A computer-readable medium containing computer-executable instructions for carrying out the computer-implemented method recited in any one of Claims 1-47.

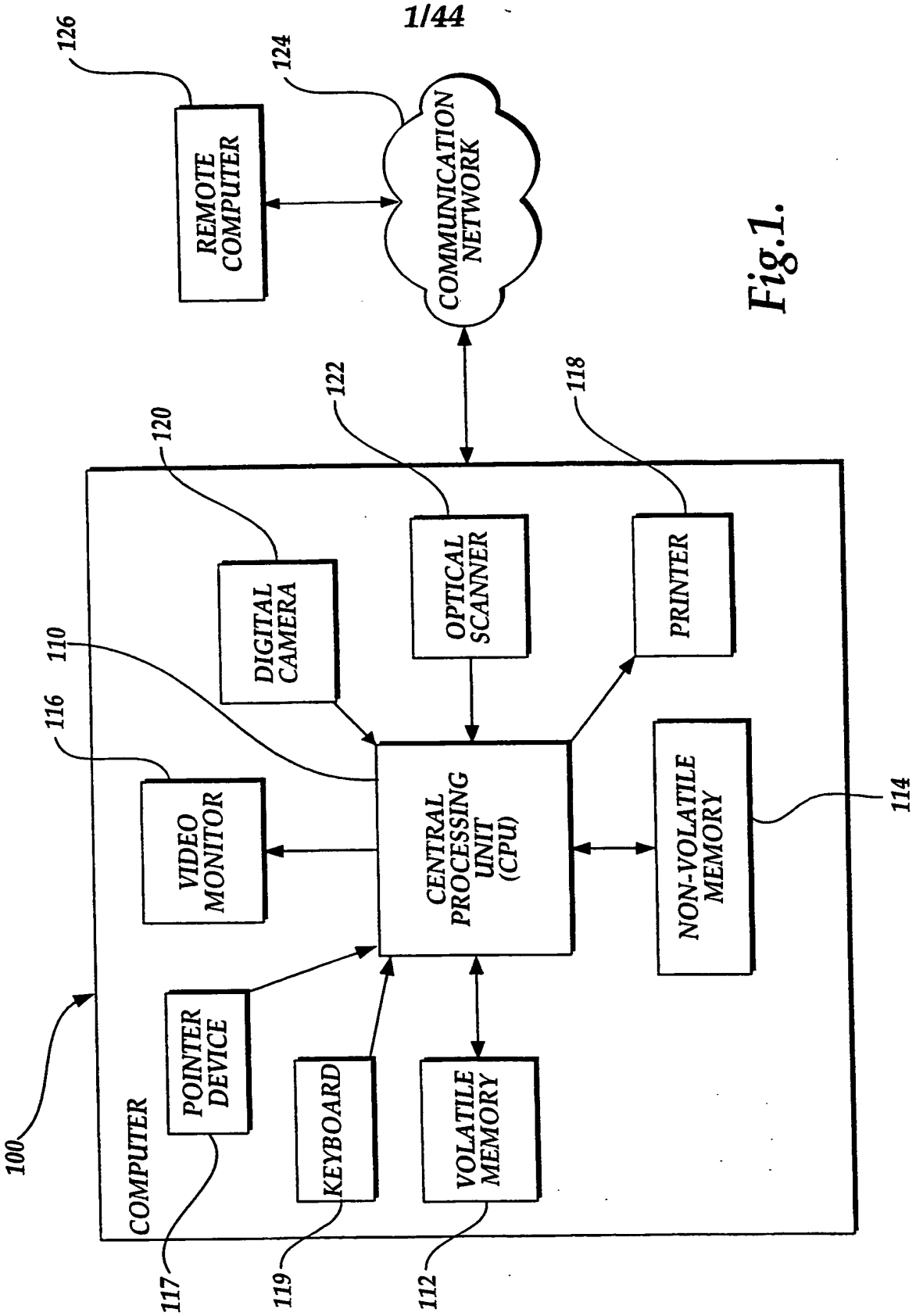

126
REMOTE COMPUTER
124
COMMUNICATION NETWORK
122
120
118
DIGITAL CAMERA
OPTICAL SCANNER
PRINTER
110
116
VIDEO MONITOR
CENTRAL PROCESSING UNIT (CPU)
NON-VOLATILE MEMORY
114
100
COMPUTER
POINTER DEVICE
KEYBOARD
VOLATILE MEMORY
117
119
112

Fig.1.

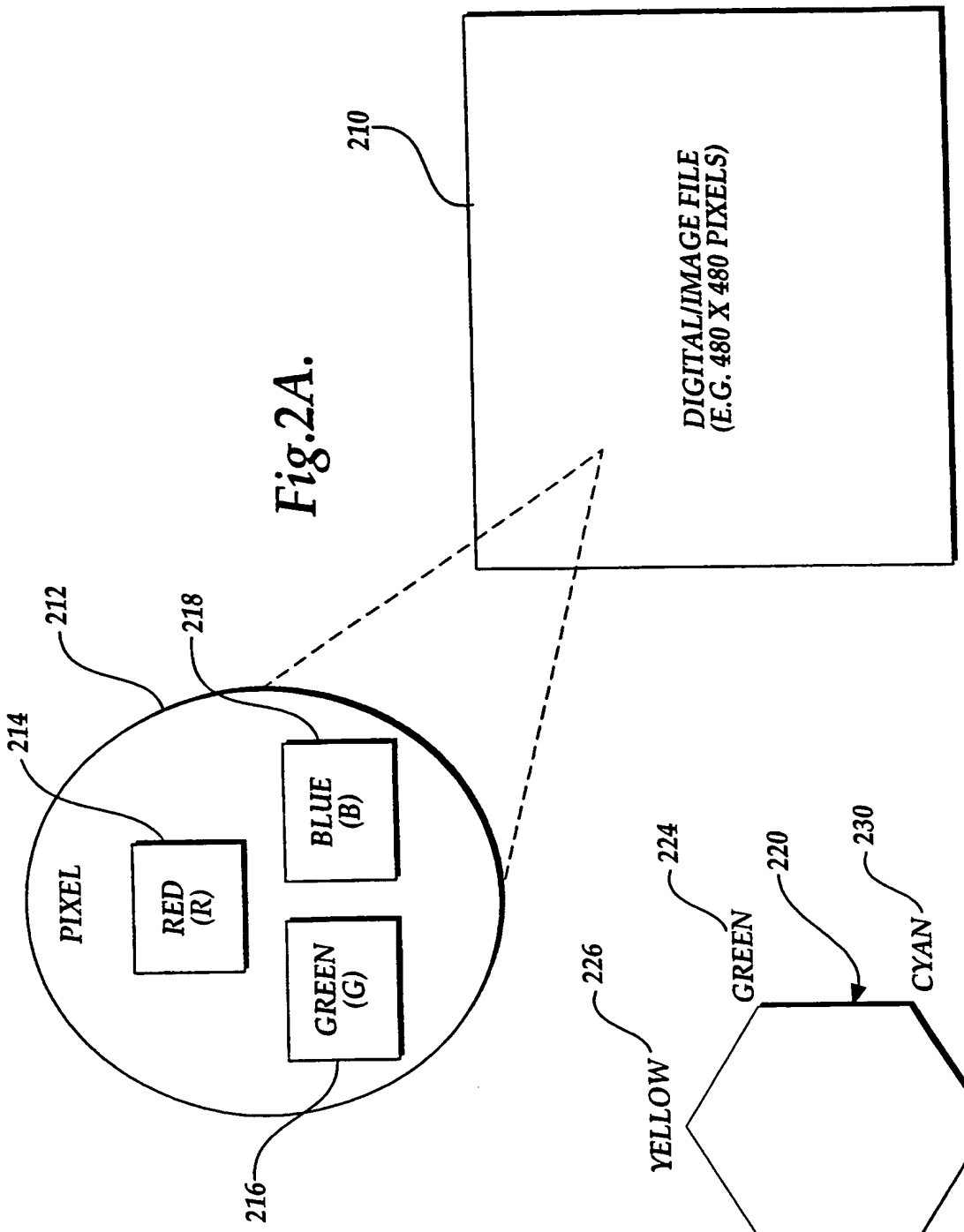

210
DIGITAL IMAGE FILE
(E.G. 480 X 480 PIXELS)
212
218
214
PIXEL
RED
(R)
BLUE
(B)
GREEN
(G)
216

Fig.2A.

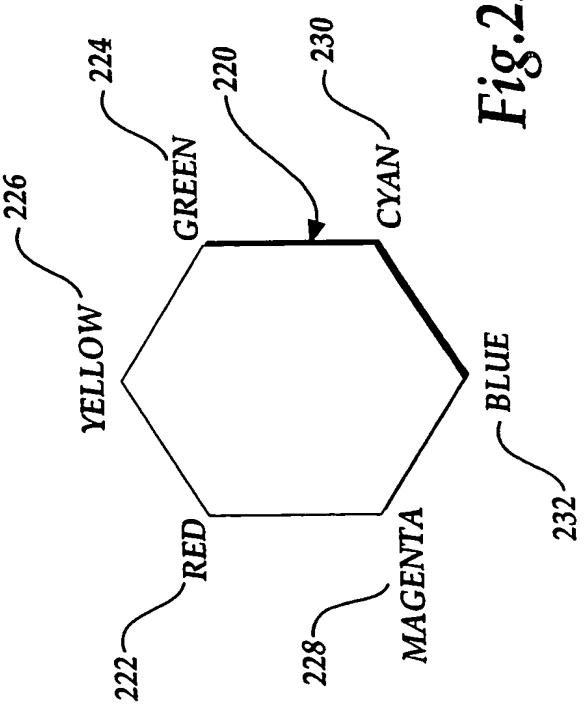

224
GREEN
220
230
CYAN
226
YELLOW
BLUE
232
RED
222
228
MAGENTA

Fig.2B.

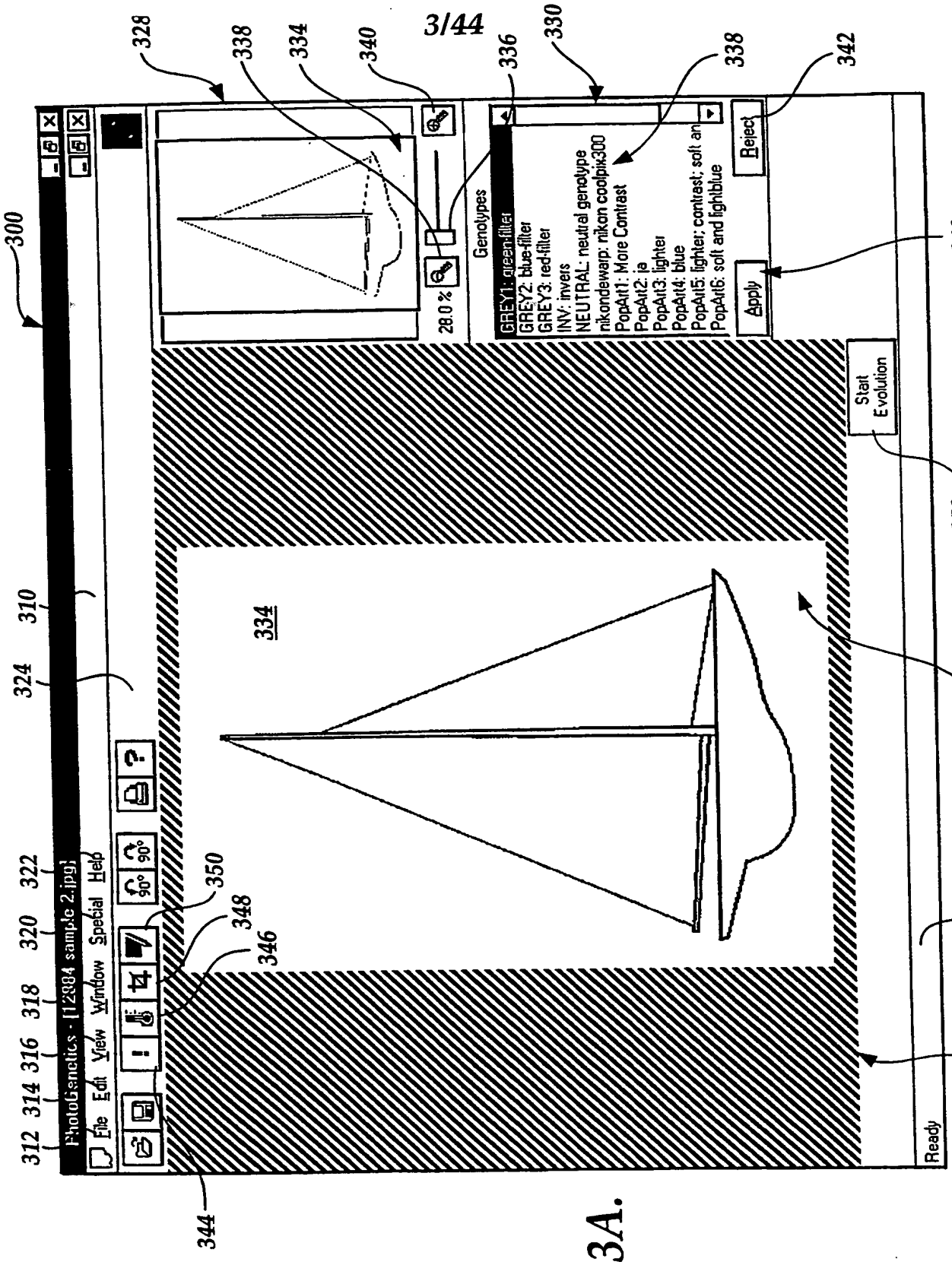

300
310
312
314
316
318
320
322
324
326
328
330
332
334
336
338
340
342
344
346
348
350
352
210
PhotoGenetics - [12384 sample 2.jpg]
File Edit View Window Special Help
28.0 %
Genotypes
GREY1: queenfilter
GREY2: blue-filter
GREY3: red-filter
INV: invers
NEUTRAL: neutral genotype
nikondewarp: nikon coolpix300
PopArt1: More Contrast
PopArt2: ja
PopArt3: lighter
PopArt4: blue
PopArt5: lighter; contrast; soft an
PopArt6: soft and lightblue
Reject
Apply
Start Evolution
Ready

Fig.3A.

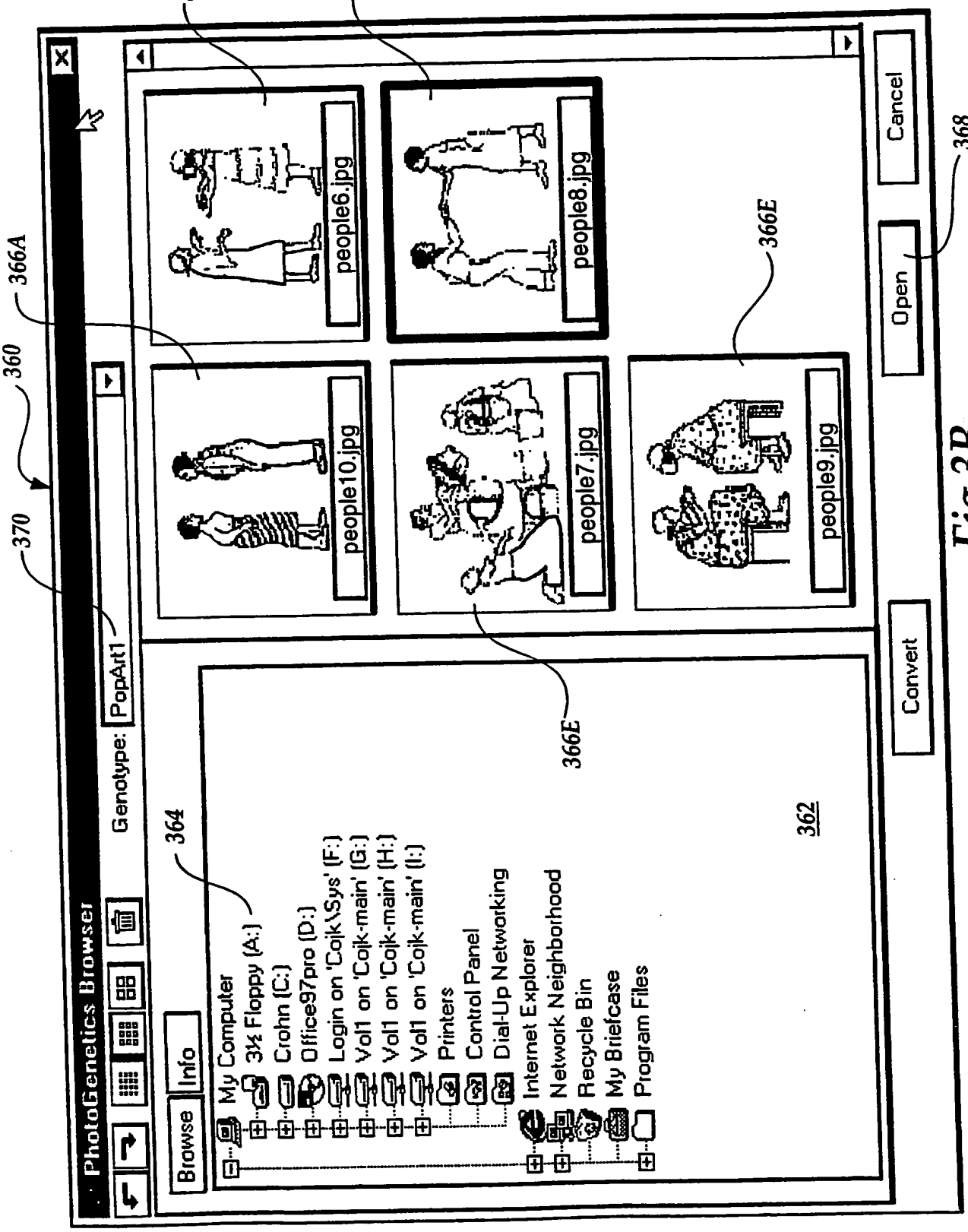

PhotoGenetics Browser
Browse
Info
Genotype:
PopArt1
My Computer
3½ Floppy (A:)
Crohn (C:)
Office97pro (D:)
Login on 'Coik\Sys' (F:)
Vol1 on 'Coik-main' (G:)
Vol1 on 'Coik-main' (H:)
Vol1 on 'Coik-main' (I:)
Printers
Control Panel
Dial-Up Networking
Internet Explorer
Network Neighborhood
Recycle Bin
My Briefcase
Program Files
people10.jpg
people6.jpg
people7.jpg
people8.jpg
people9.jpg
Convert
Open
Cancel
360
366A
366B
366D
366E
366E
362
364
368
370

Fig.3B.

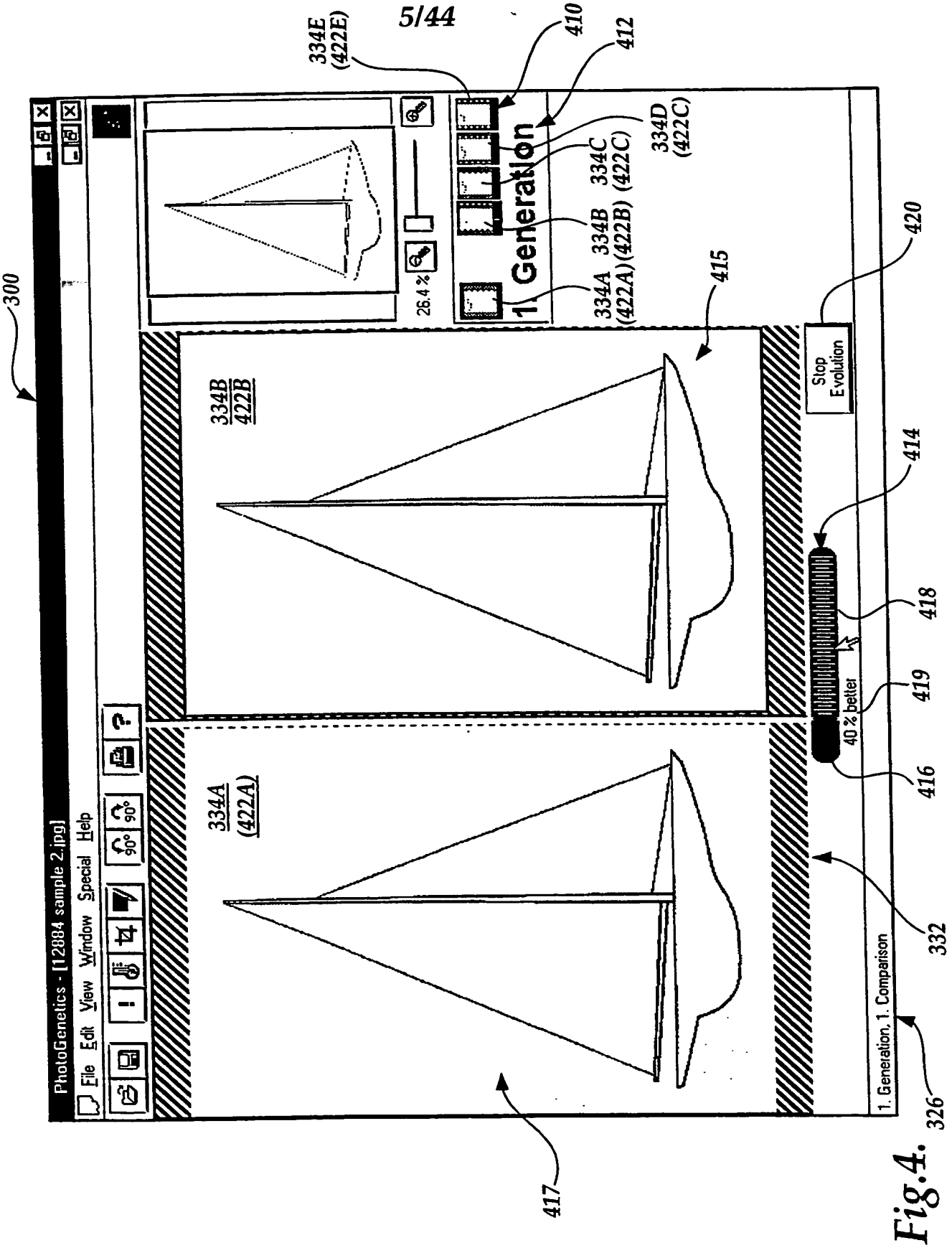

300
PhotoGenetics - [12084 sample 2.jpg]
File Edit View Window Special Help
334E (422E)
410
412
334D (422C)
334C (422C)
334B (422B)
334A (422A)
1 Generation
26.4 %
415
420
Stop Evolution
334B 422B
414
418
40 % better
419
416
334A (422A)
417
332
1. Generation, 1. Comparison
326

Fig.4.

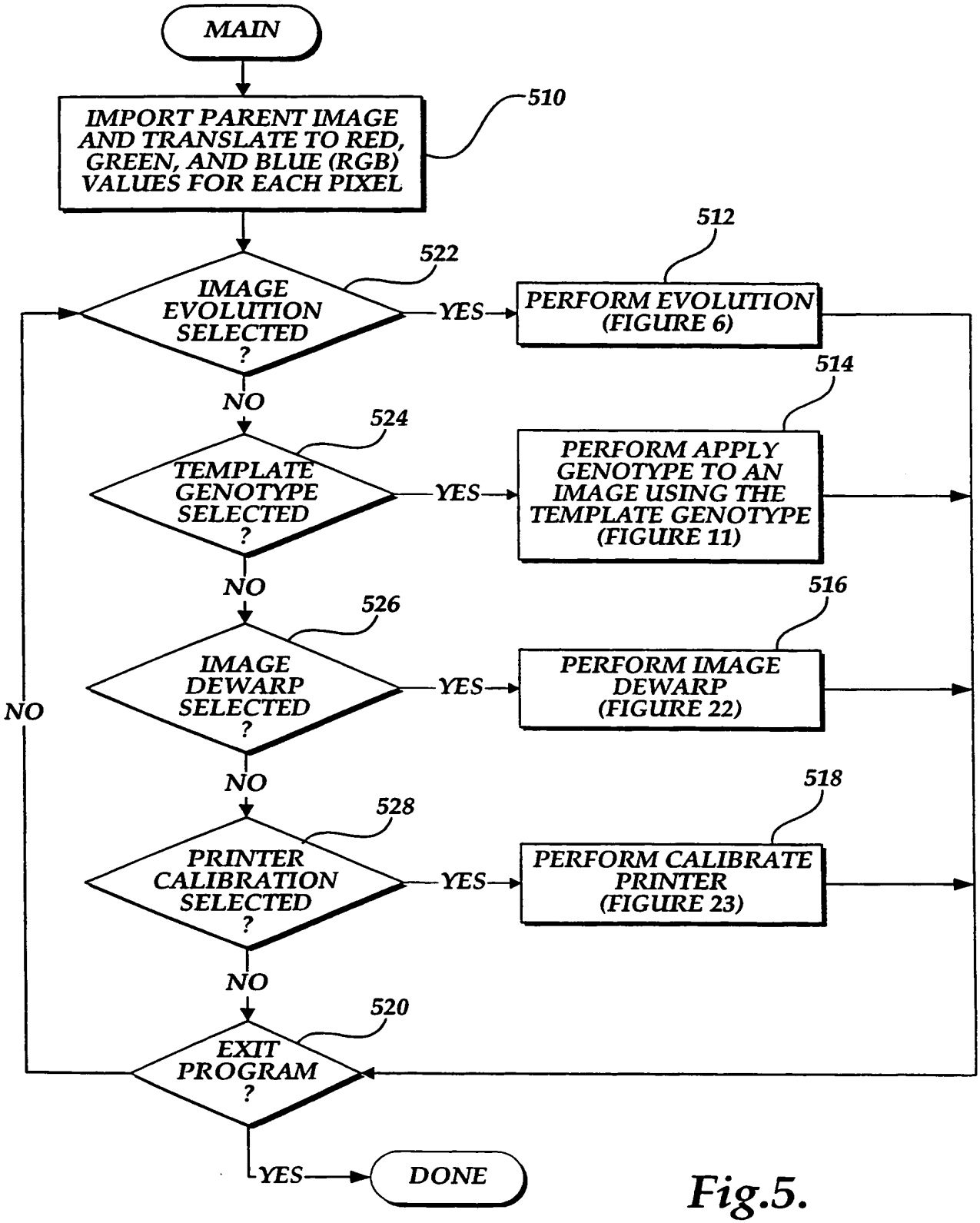

MAIN
IMPORT PARENT IMAGE AND TRANSLATE TO RED, GREEN, AND BLUE (RGB) VALUES FOR EACH PIXEL
510
IMAGE EVOLUTION SELECTED ?
522
YES
PERFORM EVOLUTION (FIGURE 6)
512
NO
TEMPLATE GENOTYPE SELECTED ?
524
YES
PERFORM APPLY GENOTYPE TO AN IMAGE USING THE TEMPLATE GENOTYPE (FIGURE 11)
514
NO
IMAGE DEWARP SELECTED ?
526
YES
PERFORM IMAGE DEWARP (FIGURE 22)
516
NO
PRINTER CALIBRATION SELECTED ?
528
YES
PERFORM CALIBRATE PRINTER (FIGURE 23)
518
NO
EXIT PROGRAM ?
520
NO
YES
DONE

Fig.5.

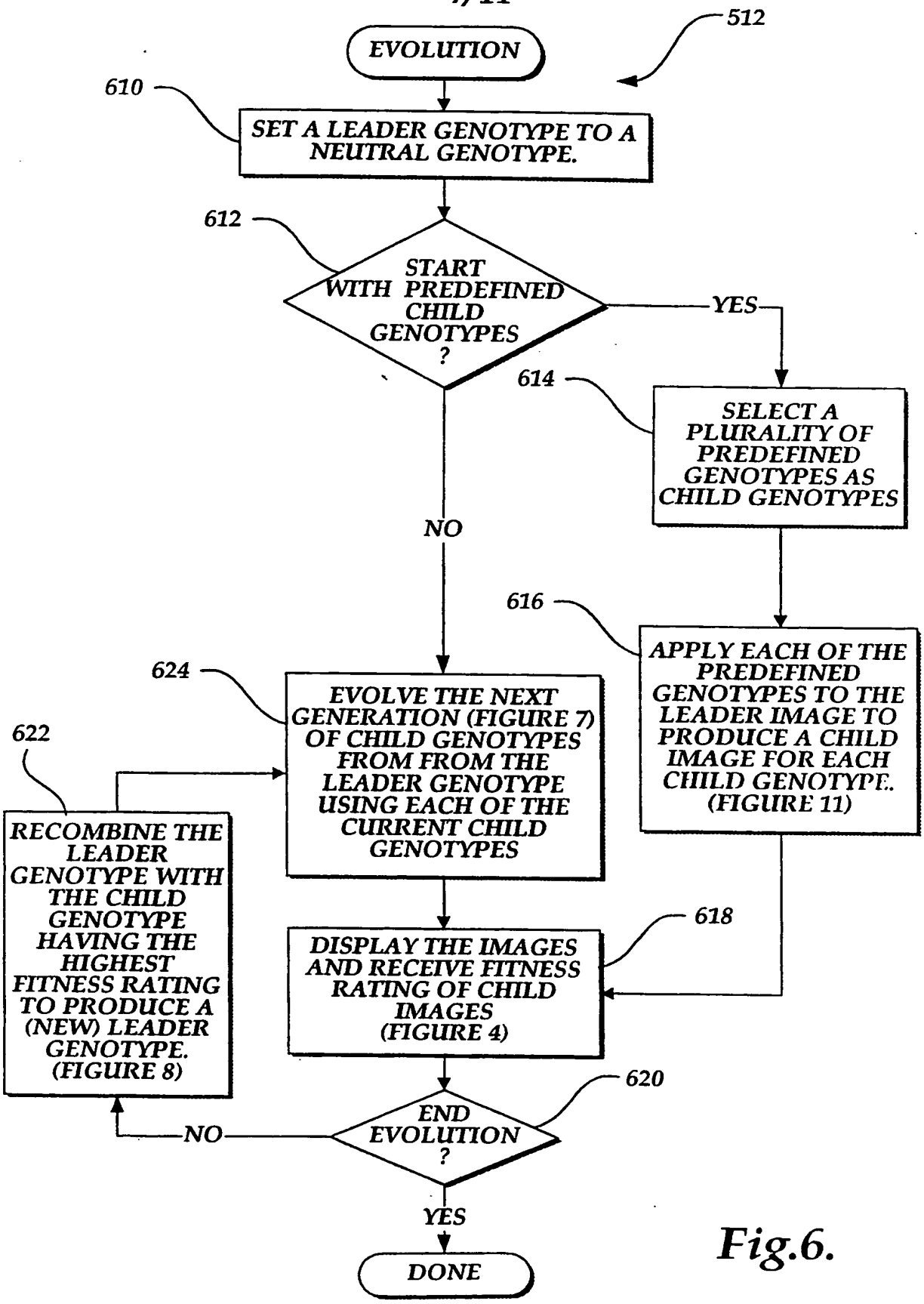

EVOLUTION
512
610
SET A LEADER GENOTYPE TO A NEUTRAL GENOTYPE.
612
START WITH PREDEFINED CHILD GENOTYPES ?
YES
614
SELECT A PLURALITY OF PREDEFINED GENOTYPES AS CHILD GENOTYPES
NO
616
APPLY EACH OF THE PREDEFINED GENOTYPES TO THE LEADER IMAGE TO PRODUCE A CHILD IMAGE FOR EACH CHILD GENOTYPE. (FIGURE 11)
624
EVOLVE THE NEXT GENERATION (FIGURE 7) OF CHILD GENOTYPES FROM FROM THE LEADER GENOTYPE USING EACH OF THE CURRENT CHILD GENOTYPES
622
RECOMBINE THE LEADER GENOTYPE WITH THE CHILD GENOTYPE HAVING THE HIGHEST FITNESS RATING TO PRODUCE A (NEW) LEADER GENOTYPE. (FIGURE 8)
618
DISPLAY THE IMAGES AND RECEIVE FITNESS RATING OF CHILD IMAGES (FIGURE 4)
620
END EVOLUTION ?
NO
YES
DONE

Fig.6.

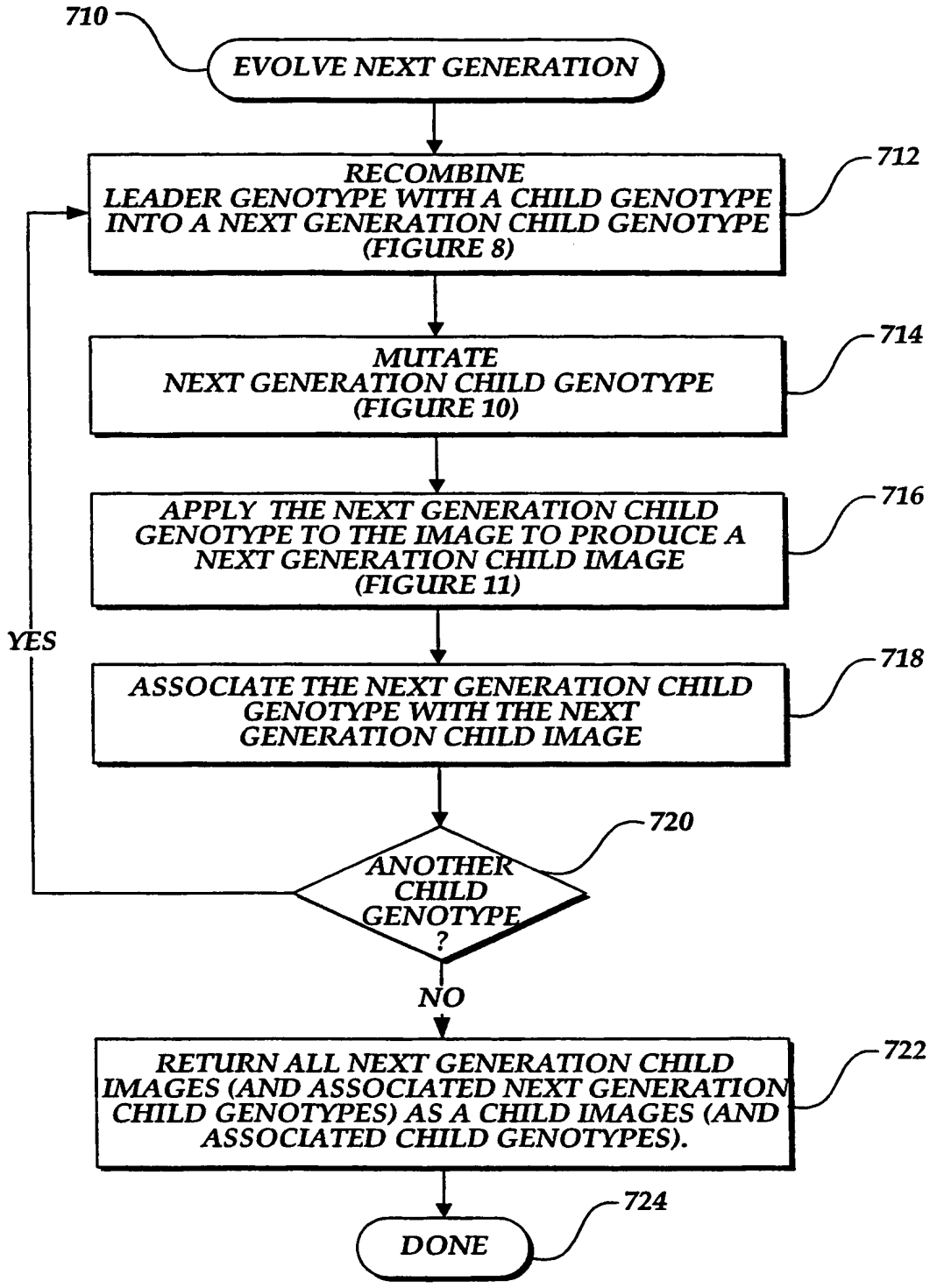

710
EVOLVE NEXT GENERATION
RECOMBINE LEADER GENOTYPE WITH A CHILD GENOTYPE INTO A NEXT GENERATION CHILD GENOTYPE (FIGURE 8)
712
MUTATE NEXT GENERATION CHILD GENOTYPE (FIGURE 10)
714
APPLY THE NEXT GENERATION CHILD GENOTYPE TO THE IMAGE TO PRODUCE A NEXT GENERATION CHILD IMAGE (FIGURE 11)
716
ASSOCIATE THE NEXT GENERATION CHILD GENOTYPE WITH THE NEXT GENERATION CHILD IMAGE
718
ANOTHER CHILD GENOTYPE ?
720
YES
NO
RETURN ALL NEXT GENERATION CHILD IMAGES (AND ASSOCIATED NEXT GENERATION CHILD GENOTYPES) AS A CHILD IMAGES (AND ASSOCIATED CHILD GENOTYPES).
722
DONE
724

Fig.7.

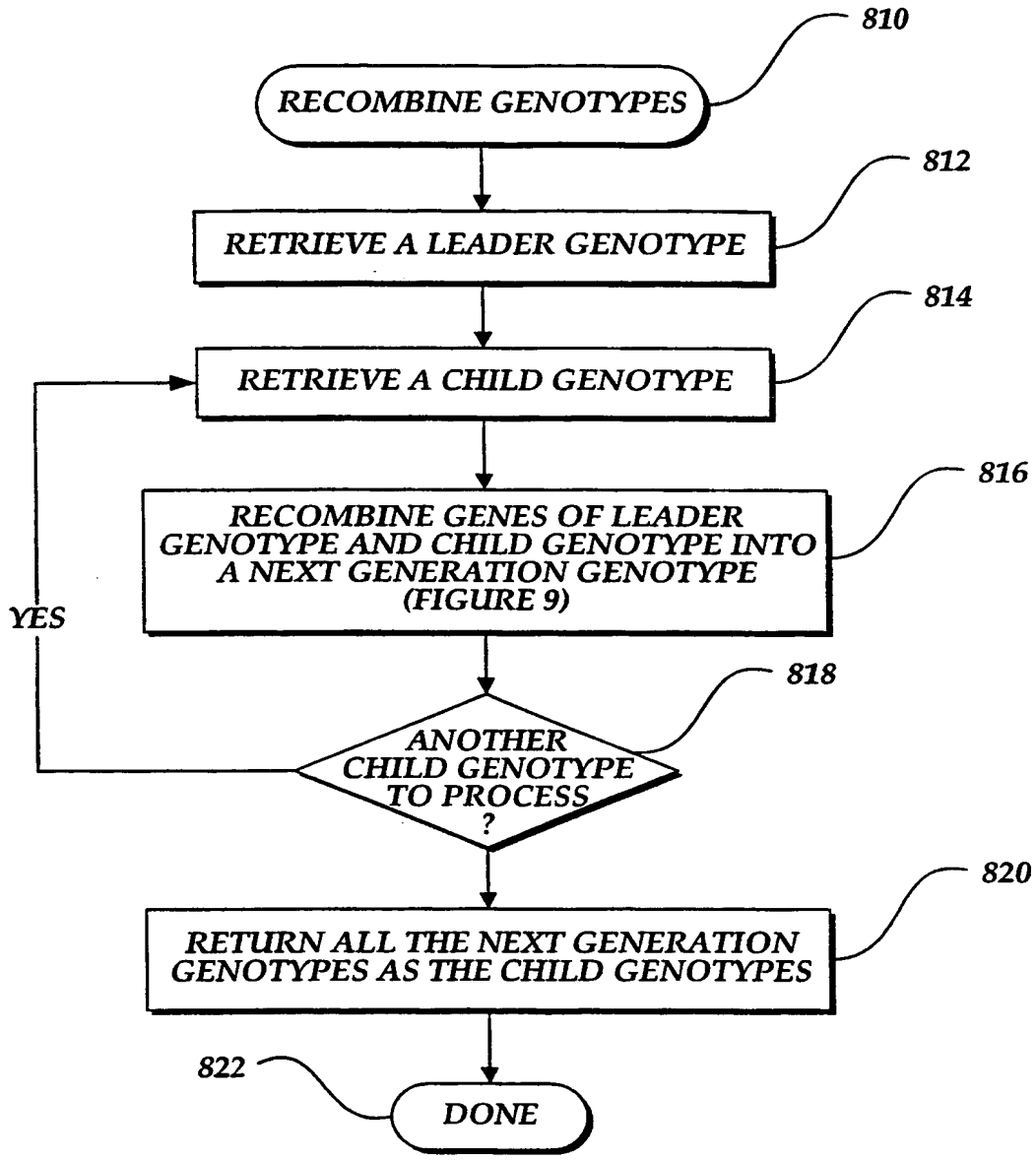

810
RECOMBINE GENOTYPES
812
RETRIEVE A LEADER GENOTYPE
814
RETRIEVE A CHILD GENOTYPE
816
RECOMBINE GENES OF LEADER GENOTYPE AND CHILD GENOTYPE INTO A NEXT GENERATION GENOTYPE (FIGURE 9)
YES
818
ANOTHER CHILD GENOTYPE TO PROCESS ?
820
RETURN ALL THE NEXT GENERATION GENOTYPES AS THE CHILD GENOTYPES
822
DONE

Fig.8.

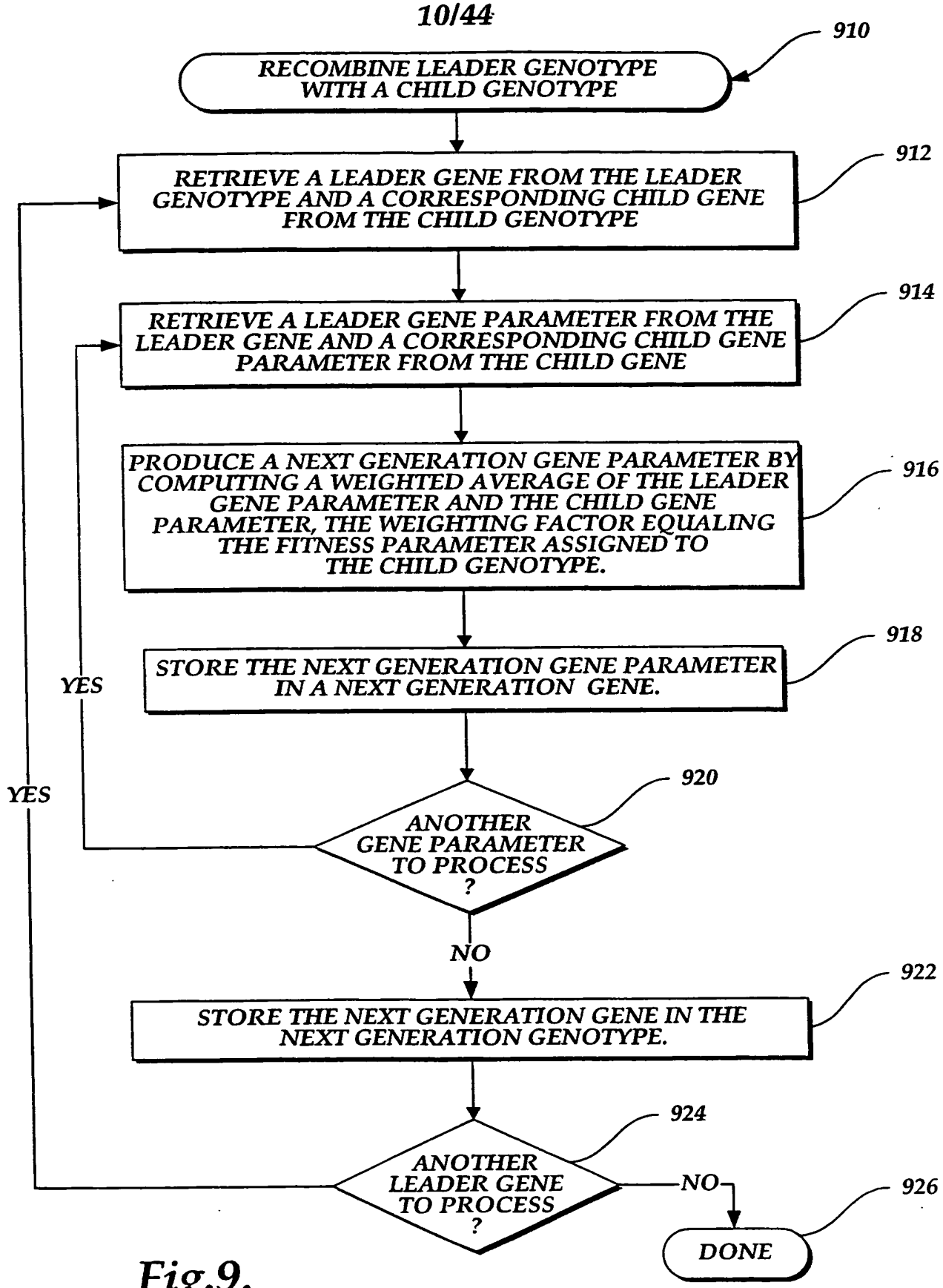

910
RECOMBINE LEADER GENOTYPE WITH A CHILD GENOTYPE
912
RETRIEVE A LEADER GENE FROM THE LEADER GENOTYPE AND A CORRESPONDING CHILD GENE FROM THE CHILD GENOTYPE
914
RETRIEVE A LEADER GENE PARAMETER FROM THE LEADER GENE AND A CORRESPONDING CHILD GENE PARAMETER FROM THE CHILD GENE
916
PRODUCE A NEXT GENERATION GENE PARAMETER BY COMPUTING A WEIGHTED AVERAGE OF THE LEADER GENE PARAMETER AND THE CHILD GENE PARAMETER, THE WEIGHTING FACTOR EQUALING THE FITNESS PARAMETER ASSIGNED TO THE CHILD GENOTYPE.
918
STORE THE NEXT GENERATION GENE PARAMETER IN A NEXT GENERATION GENE.
YES
920
ANOTHER GENE PARAMETER TO PROCESS ?
YES
NO
922
STORE THE NEXT GENERATION GENE IN THE NEXT GENERATION GENOTYPE.
924
ANOTHER LEADER GENE TO PROCESS ?
NO
926
DONE

Fig.9.

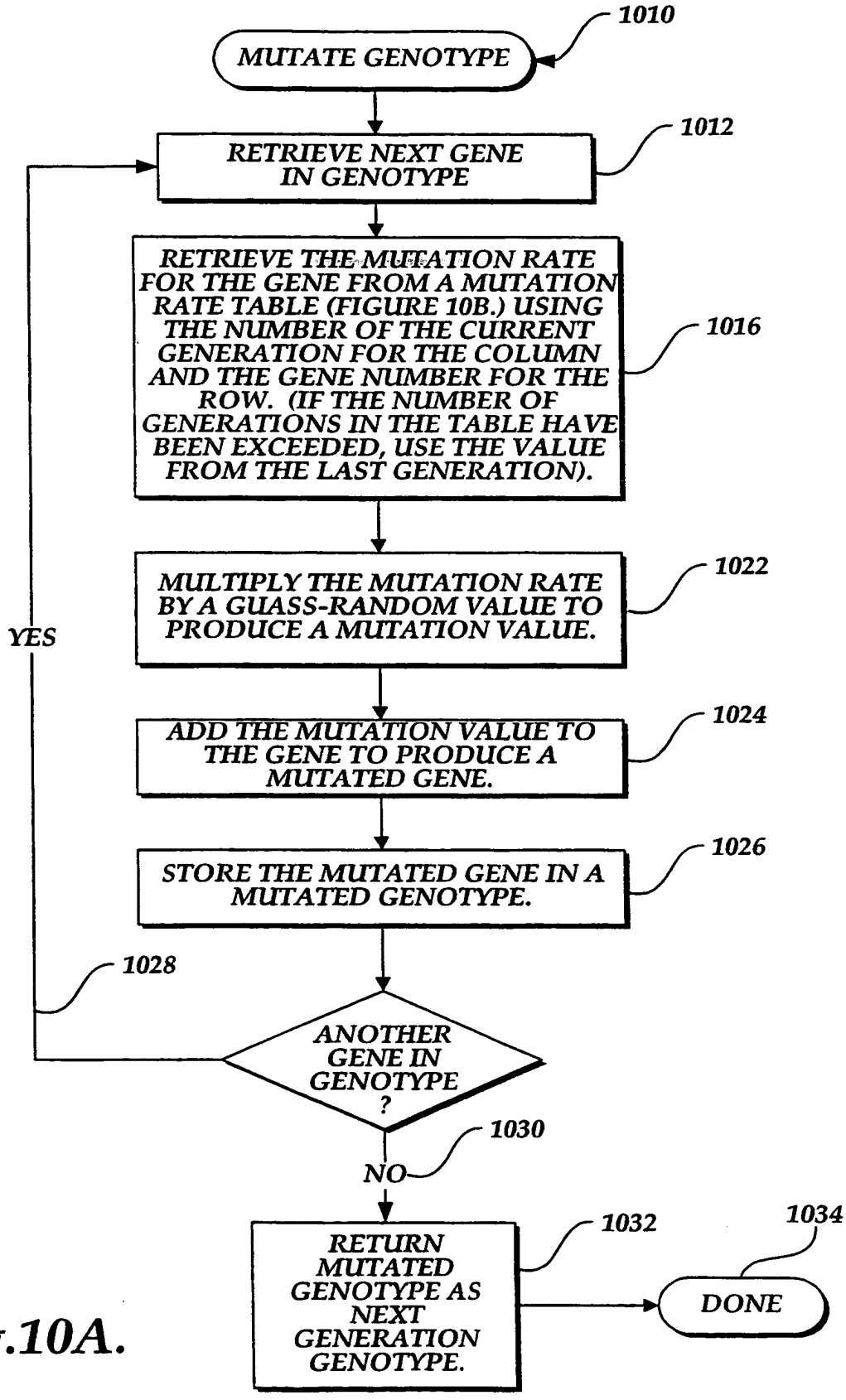

1010
MUTATE GENOTYPE
1012
RETRIEVE NEXT GENE IN GENOTYPE
RETRIEVE THE MUTATION RATE FOR THE GENE FROM A MUTATION RATE TABLE (FIGURE 10B.) USING THE NUMBER OF THE CURRENT GENERATION FOR THE COLUMN AND THE GENE NUMBER FOR THE ROW. (IF THE NUMBER OF GENERATIONS IN THE TABLE HAVE BEEN EXCEEDED, USE THE VALUE FROM THE LAST GENERATION).
1016
MULTIPLY THE MUTATION RATE BY A GUASS-RANDOM VALUE TO PRODUCE A MUTATION VALUE.
1022
YES
ADD THE MUTATION VALUE TO THE GENE TO PRODUCE A MUTATED GENE.
1024
STORE THE MUTATED GENE IN A MUTATED GENOTYPE.
1026
1028
ANOTHER GENE IN GENOTYPE ?
1030
NO
RETURN MUTATED GENOTYPE AS NEXT GENERATION GENOTYPE.
1032
1034
DONE

Fig.10A.

1016 *Mutation Rate Table*
(all values hex)

	Gen. 1	Gen. 2	Gen. 3	Gen. 4	Gen. 5	Gen. 6	Gen. 7	Gen. 8
Gene1	0	0A	10	14	14	14	14	14
Gene2	0	20	20	20	20	20	20	20
Gene4	0	20	18	18	18	18	12	10
Gene5	0	25	25	25	23	22	20	20
Gene6	0	20	22	23	24	25	26	27
Gene7	0	30	35	35	35	35	35	35
	Gen. 9	Gen. 10	Gen. 11	Gen. 12	Gen. 13	Gen. 14	Gen. 15	Gen. 16
Gene1	14	14	14	14	14	14	14	14
Gene2	20	20	20	20	20	20	20	20
Gene4	10	10	10	10	10	10	10	10
Gene5	1A	1A	1A	1A	1A	1A	1A	1A
Gene6	28	28	28	28	28	28	28	28
Gene7	35	35	35	35	35	35	35	35

1018

GENE #

GENERATION #

Fig.10B.

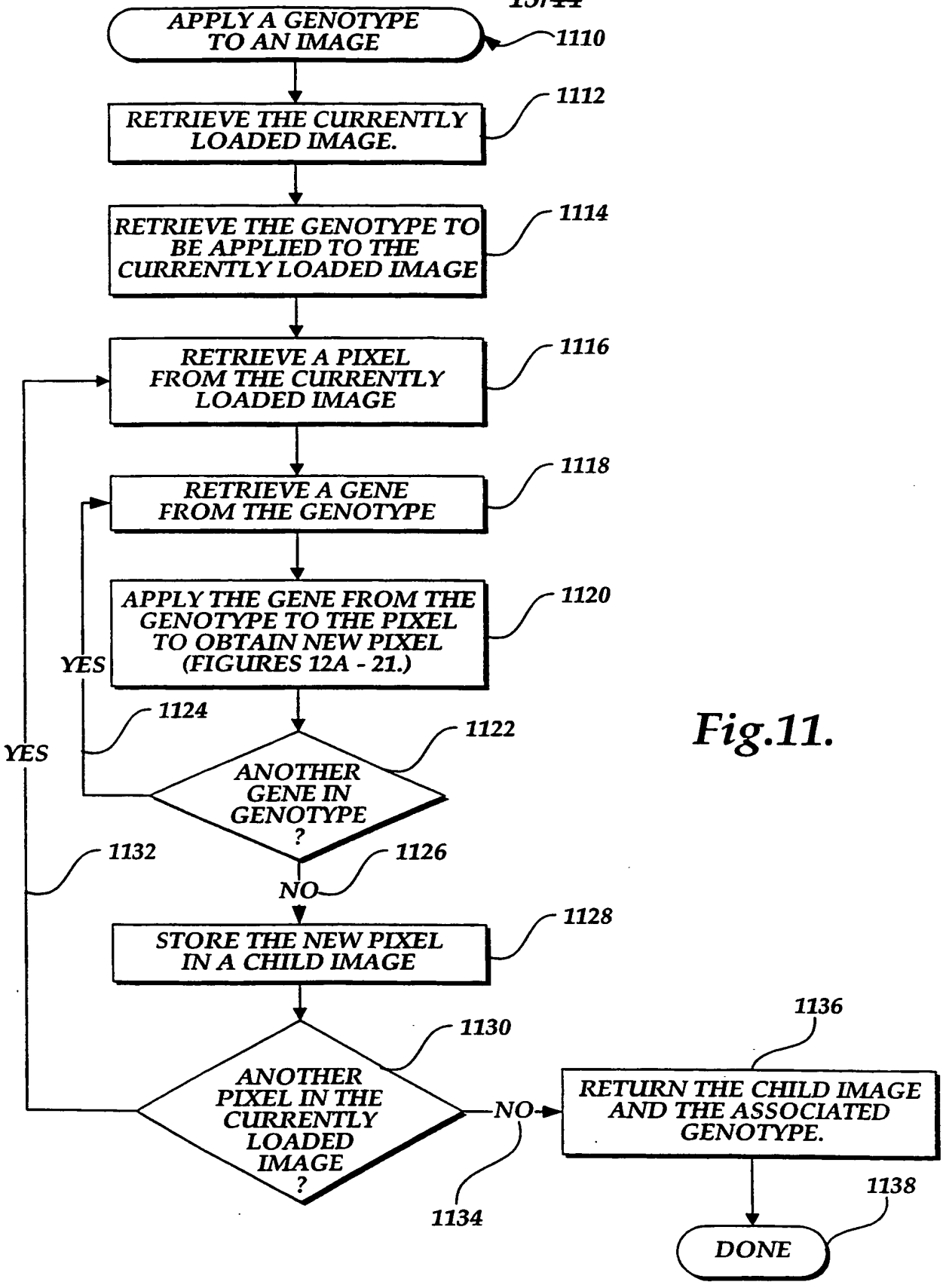

APPLY A GENOTYPE TO AN IMAGE
1110
RETRIEVE THE CURRENTLY LOADED IMAGE.
1112
RETRIEVE THE GENOTYPE TO BE APPLIED TO THE CURRENTLY LOADED IMAGE
1114
RETRIEVE A PIXEL FROM THE CURRENTLY LOADED IMAGE
1116
RETRIEVE A GENE FROM THE GENOTYPE
1118
APPLY THE GENE FROM THE GENOTYPE TO THE PIXEL TO OBTAIN NEW PIXEL (FIGURES 12A - 21.)
1120
YES
1124
YES
ANOTHER GENE IN GENOTYPE ?
1122
1132
1126
NO
STORE THE NEW PIXEL IN A CHILD IMAGE
1128
1130
ANOTHER PIXEL IN THE CURRENTLY LOADED IMAGE ?
NO
1134
1136
RETURN THE CHILD IMAGE AND THE ASSOCIATED GENOTYPE.
1138
DONE

Fig.11.

Fig.12A.

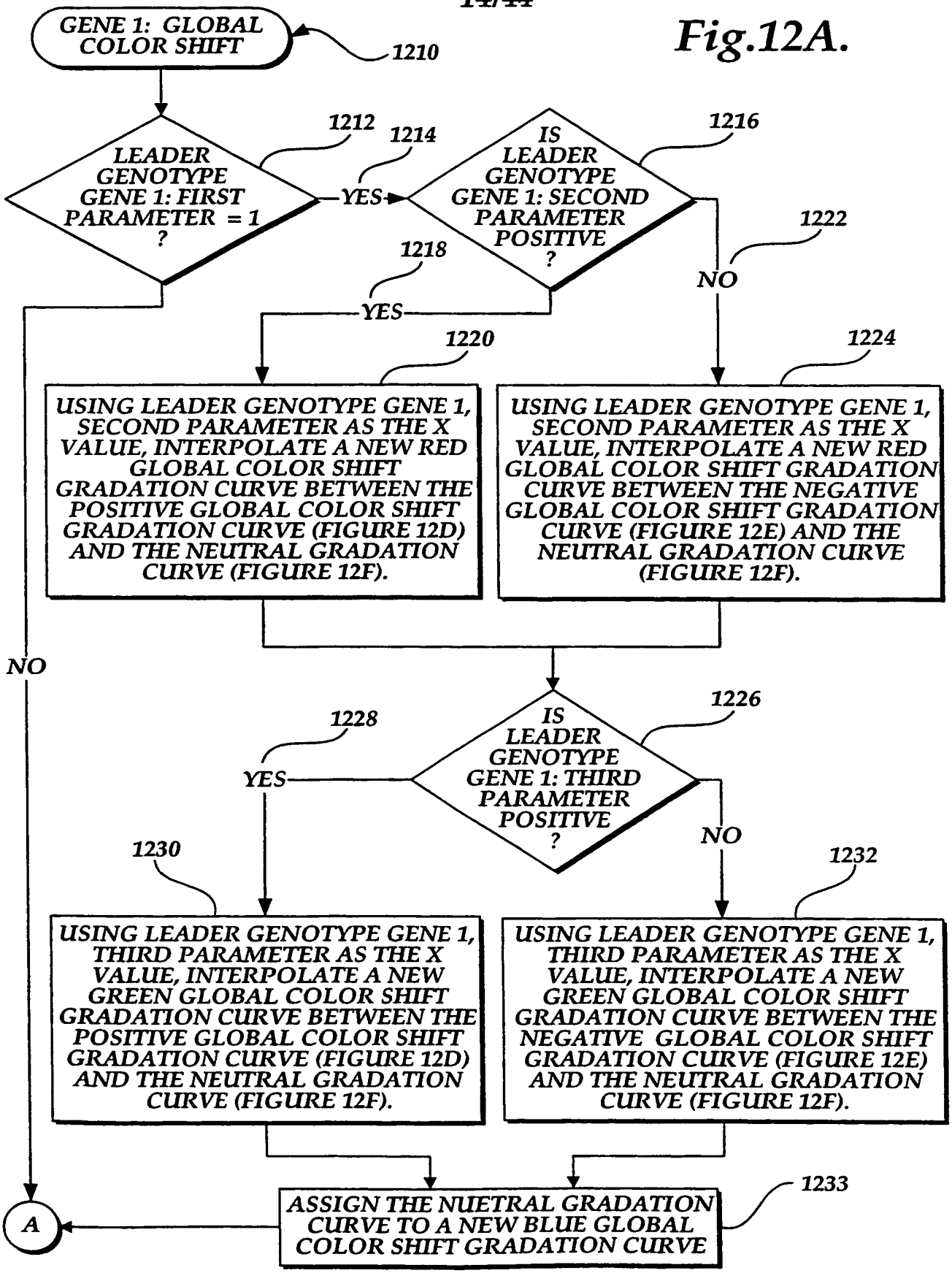

GENE 1: GLOBAL COLOR SHIFT
1210
LEADER GENOTYPE GENE 1: FIRST PARAMETER = 1 ?
1212
1214
YES
IS LEADER GENOTYPE GENE 1: SECOND PARAMETER POSITIVE ?
1216
1218
YES
1222
NO
NO
1220
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW RED GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1224
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW RED GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1226
IS LEADER GENOTYPE GENE 1: THIRD PARAMETER POSITIVE ?
1228
YES
NO
1230
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW GREEN GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1232
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW GREEN GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
ASSIGN THE NUETRAL GRADATION CURVE TO A NEW BLUE GLOBAL COLOR SHIFT GRADATION CURVE
1233
A

Fig.12B.

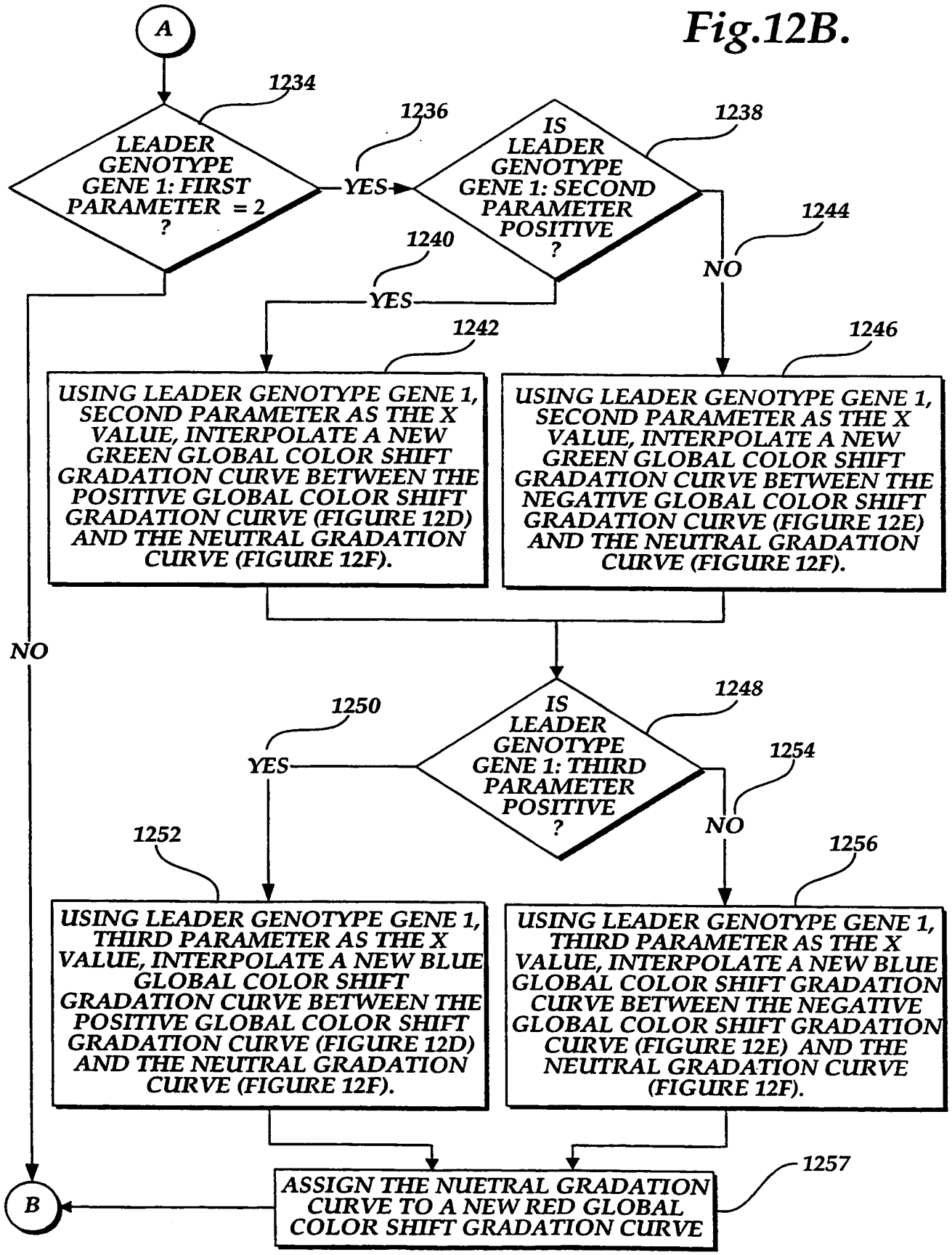
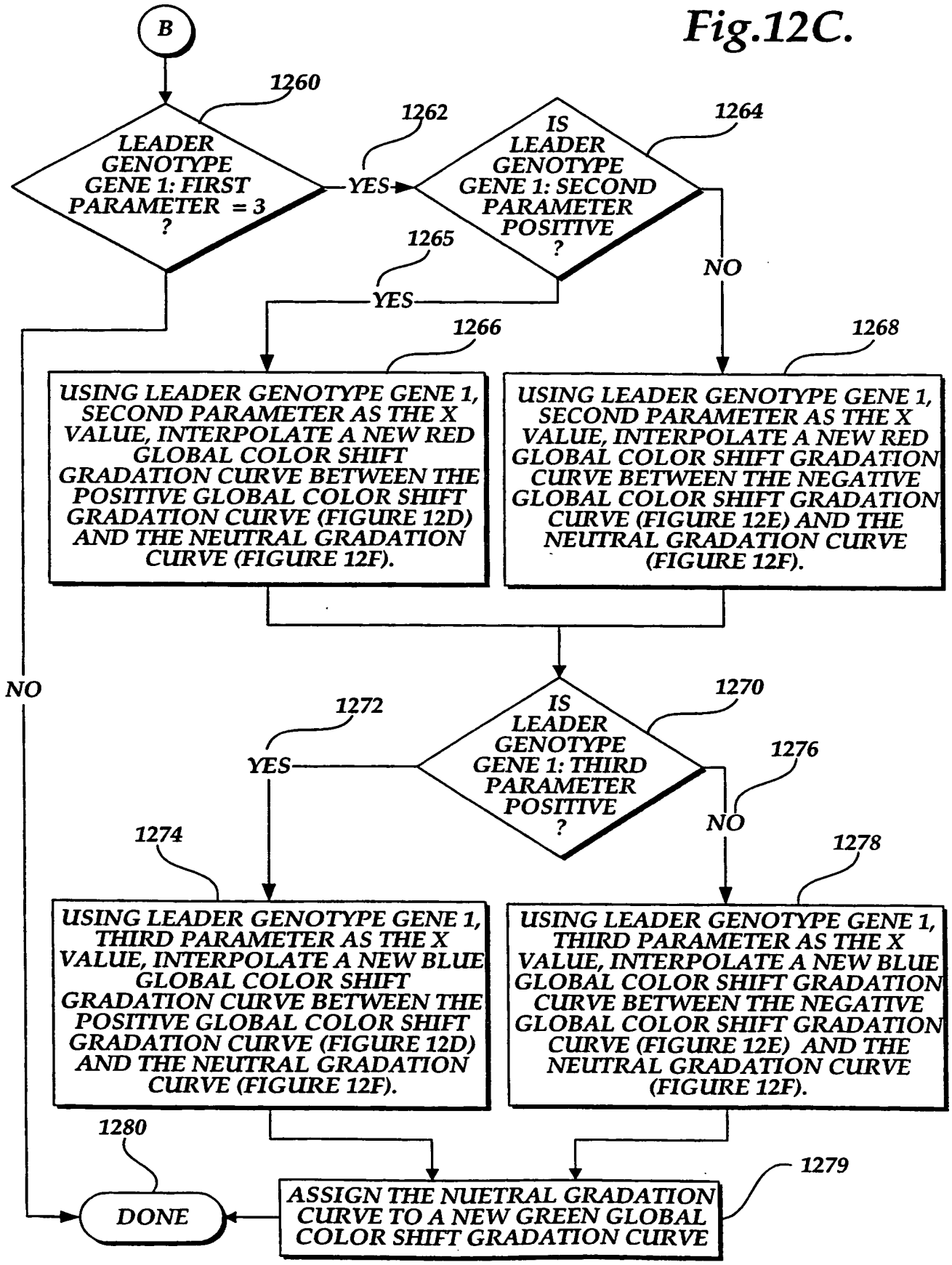

A
1234
LEADER GENOTYPE GENE 1: FIRST PARAMETER = 2 ?
1236
YES
1238
IS LEADER GENOTYPE GENE 1: SECOND PARAMETER POSITIVE ?
1240
YES
1244
NO
NO
1242
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW GREEN GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1246
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW GREEN GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1248
IS LEADER GENOTYPE GENE 1: THIRD PARAMETER POSITIVE ?
1250
YES
1254
NO
1252
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW BLUE GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1256
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW BLUE GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1257
ASSIGN THE NUETRAL GRADATION CURVE TO A NEW RED GLOBAL COLOR SHIFT GRADATION CURVE
B

Fig.12C.


B
1260
LEADER GENOTYPE GENE 1: FIRST PARAMETER = 3 ?
1262
YES
1264
IS LEADER GENOTYPE GENE 1: SECOND PARAMETER POSITIVE ?
NO
1265
YES
1266
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW RED GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1268
USING LEADER GENOTYPE GENE 1, SECOND PARAMETER AS THE X VALUE, INTERPOLATE A NEW RED GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
NO
1270
IS LEADER GENOTYPE GENE 1: THIRD PARAMETER POSITIVE ?
1272
YES
1276
NO
1274
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW BLUE GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE POSITIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1278
USING LEADER GENOTYPE GENE 1, THIRD PARAMETER AS THE X VALUE, INTERPOLATE A NEW BLUE GLOBAL COLOR SHIFT GRADATION CURVE BETWEEN THE NEGATIVE GLOBAL COLOR SHIFT GRADATION CURVE (FIGURE 12E) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F).
1280
DONE
1279
ASSIGN THE NUETRAL GRADATION CURVE TO A NEW GREEN GLOBAL COLOR SHIFT GRADATION CURVE

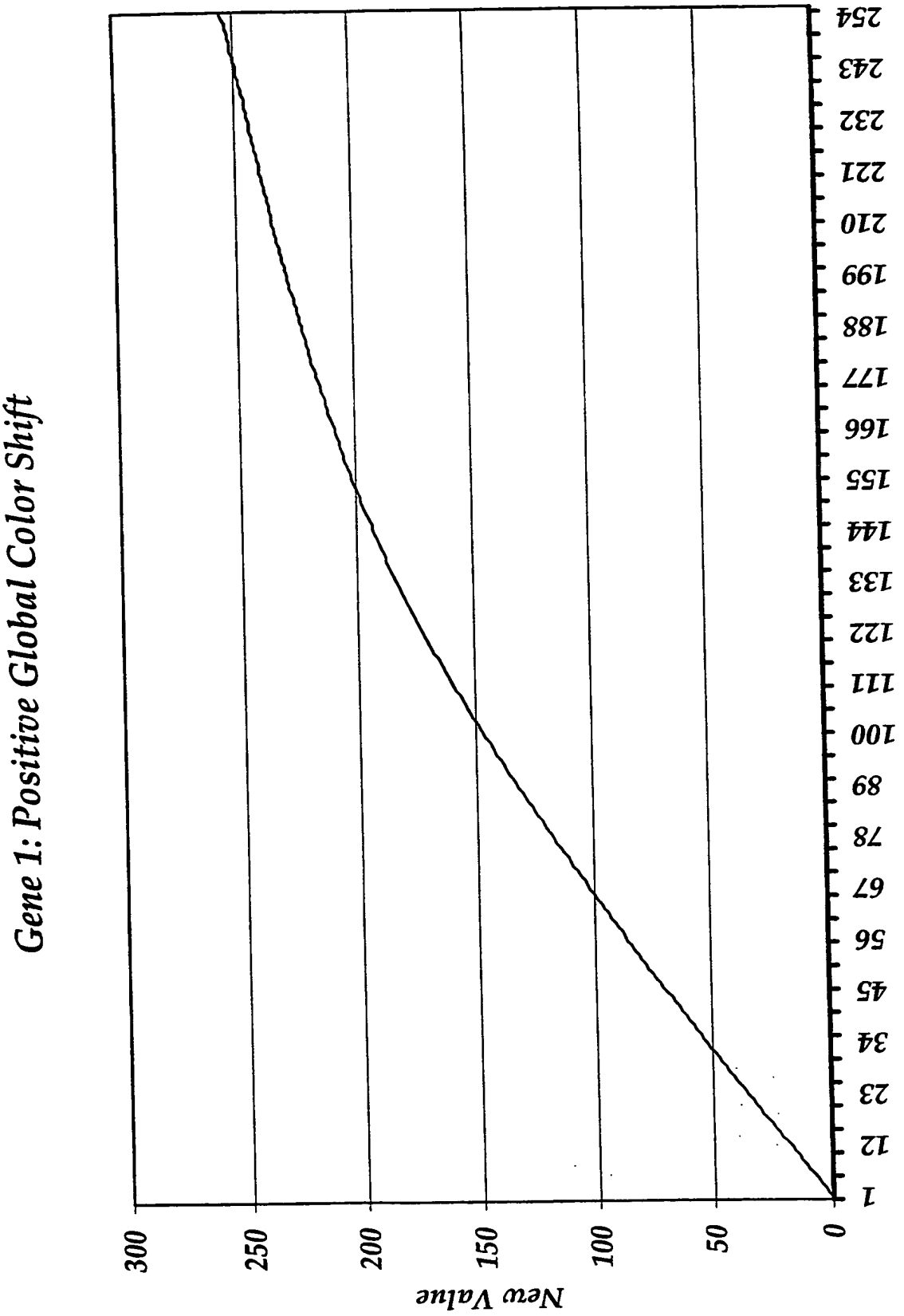

Gene 1: Positive Global Color Shift
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.12D.

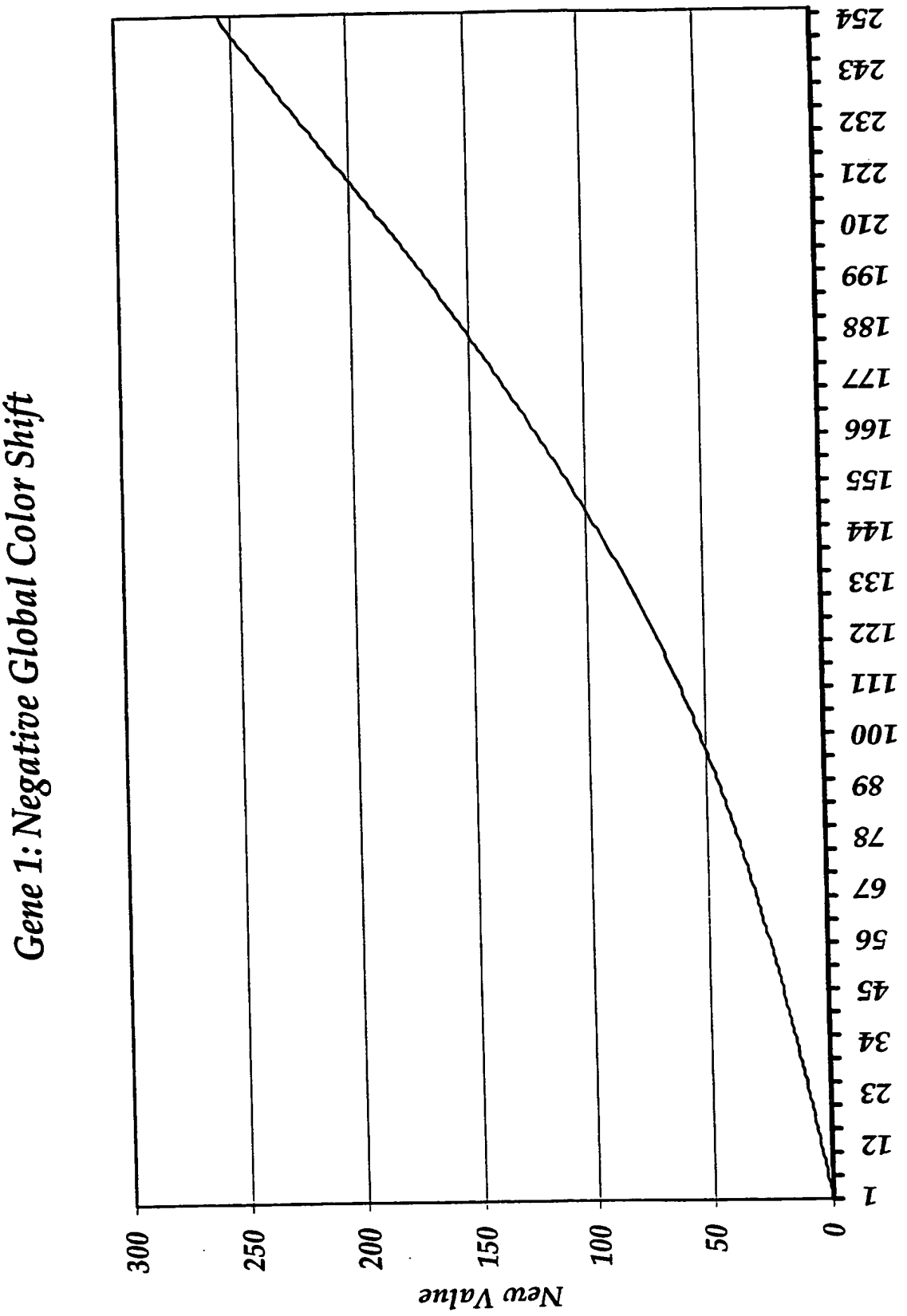

Gene 1: Negative Global Color Shift
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.12E.

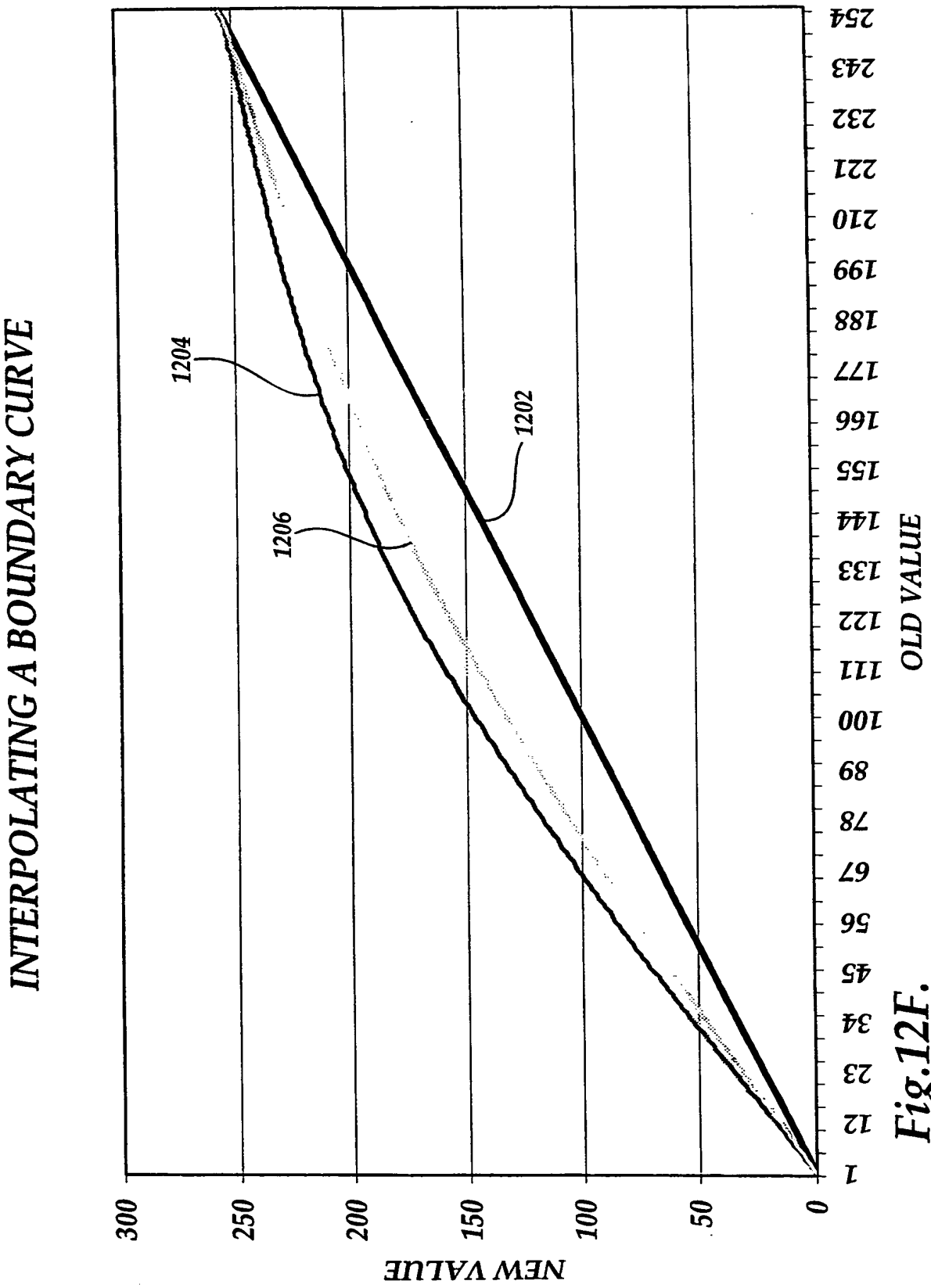

INTERPOLATING A BOUNDARY CURVE
1204
1202
1206
NEW VALUE
300
250
200
150
100
50
0
OLD VALUE
254
243
232
221
210
199
188
177
166
155
144
133
122
111
100
89
78
67
56
45
34
23
12
1

Fig.12F.

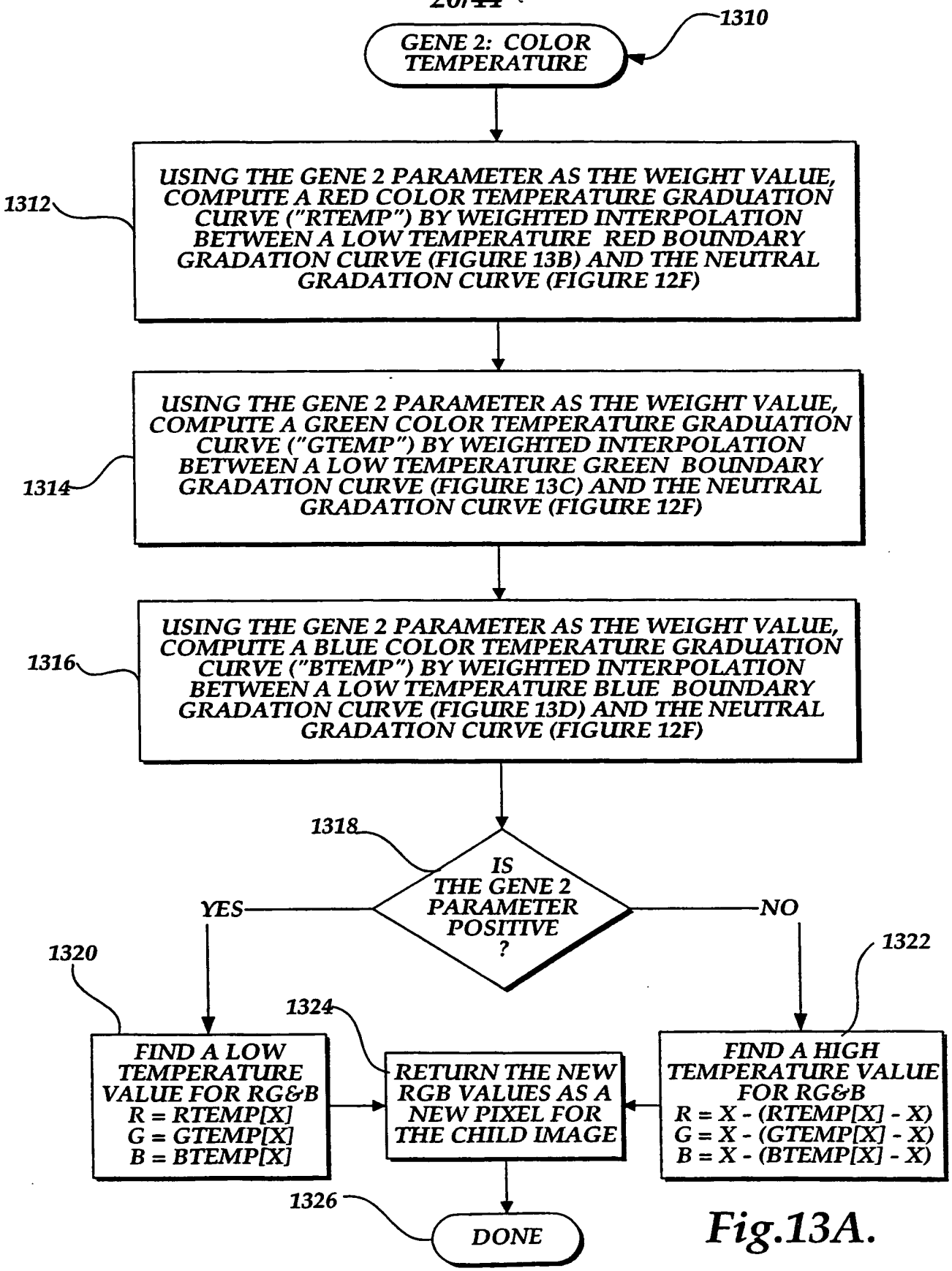

GENE 2: COLOR TEMPERATURE
1310
USING THE GENE 2 PARAMETER AS THE WEIGHT VALUE, COMPUTE A RED COLOR TEMPERATURE GRADUATION CURVE ("RTEMP") BY WEIGHTED INTERPOLATION BETWEEN A LOW TEMPERATURE RED BOUNDARY GRADATION CURVE (FIGURE 13B) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F)
1312
USING THE GENE 2 PARAMETER AS THE WEIGHT VALUE, COMPUTE A GREEN COLOR TEMPERATURE GRADUATION CURVE ("GTEMP") BY WEIGHTED INTERPOLATION BETWEEN A LOW TEMPERATURE GREEN BOUNDARY GRADATION CURVE (FIGURE 13C) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F)
1314
USING THE GENE 2 PARAMETER AS THE WEIGHT VALUE, COMPUTE A BLUE COLOR TEMPERATURE GRADUATION CURVE ("BTEMP") BY WEIGHTED INTERPOLATION BETWEEN A LOW TEMPERATURE BLUE BOUNDARY GRADATION CURVE (FIGURE 13D) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F)
1316
1318
IS THE GENE 2 PARAMETER POSITIVE ?
YES
NO
1320
FIND A LOW TEMPERATURE VALUE FOR RG&B
R = RTEMP[X]
G = GTEMP[X]
B = BTEMP[X]
1322
FIND A HIGH TEMPERATURE VALUE FOR RG&B
R = X - (RTEMP[X] - X)
G = X - (GTEMP[X] - X)
B = X - (BTEMP[X] - X)
1324
RETURN THE NEW RGB VALUES AS A NEW PIXEL FOR THE CHILD IMAGE
1326
DONE

Fig.13A.

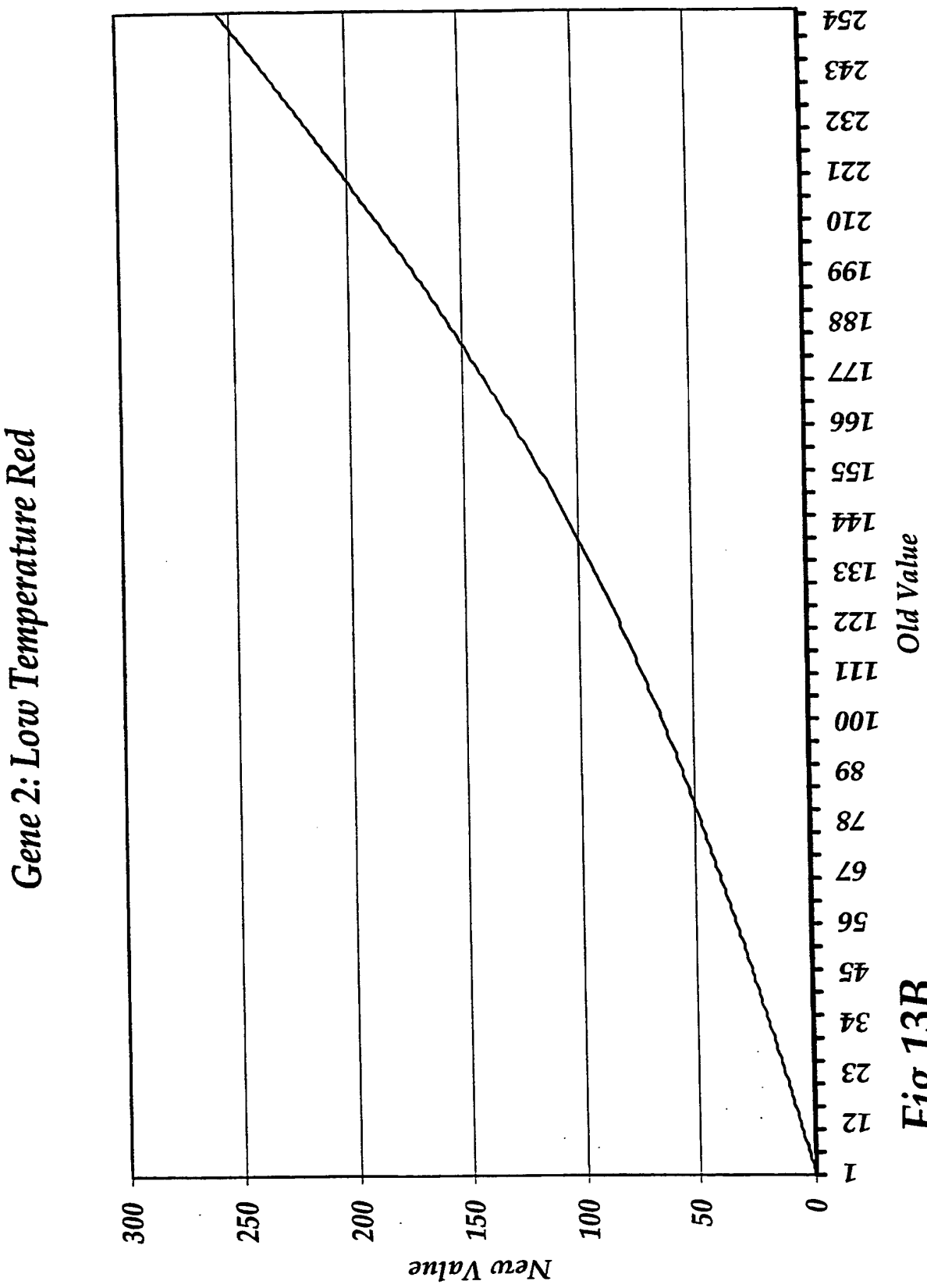

Gene 2: Low Temperature Red
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.13B.

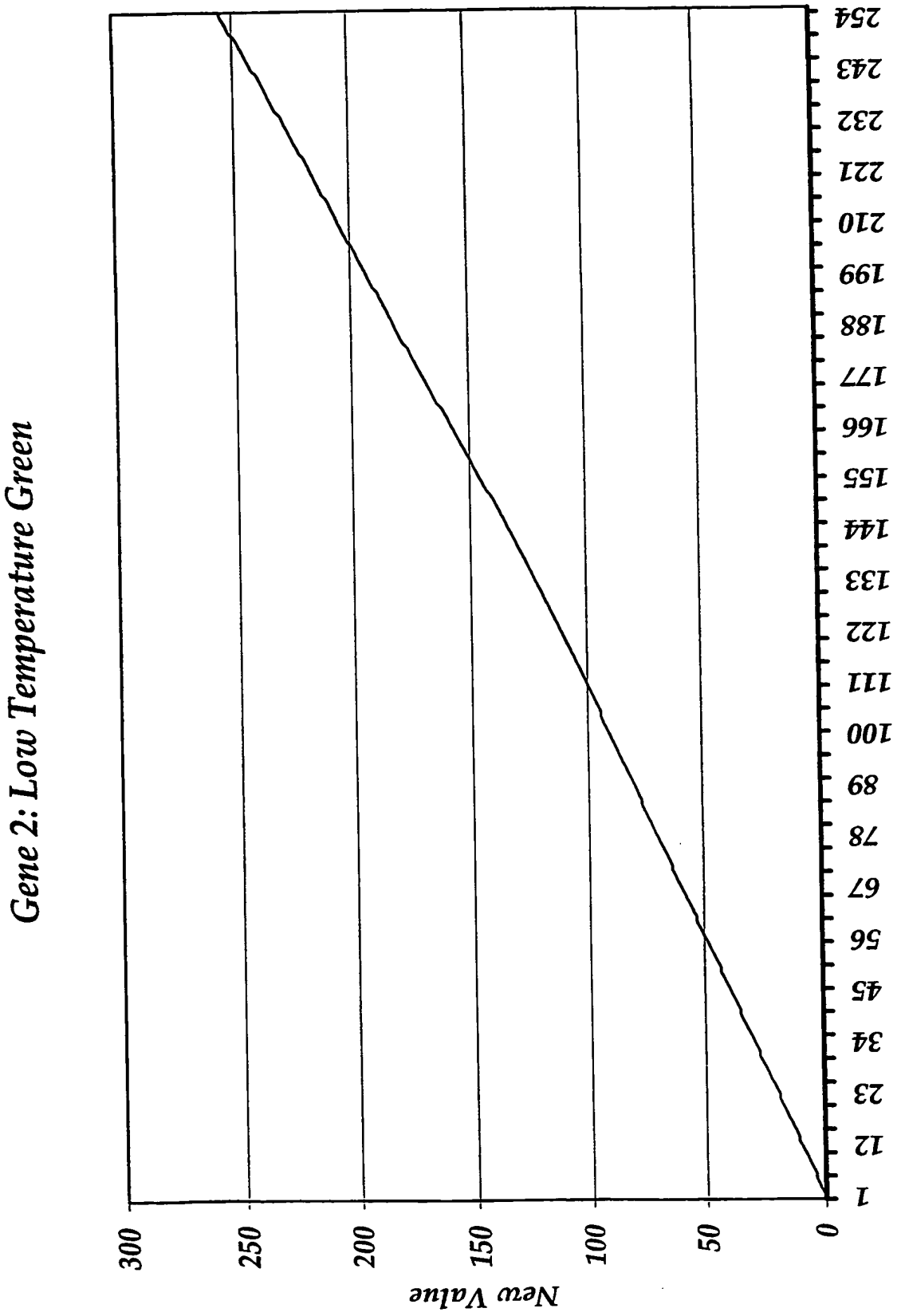

Gene 2: Low Temperature Green
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.13C.

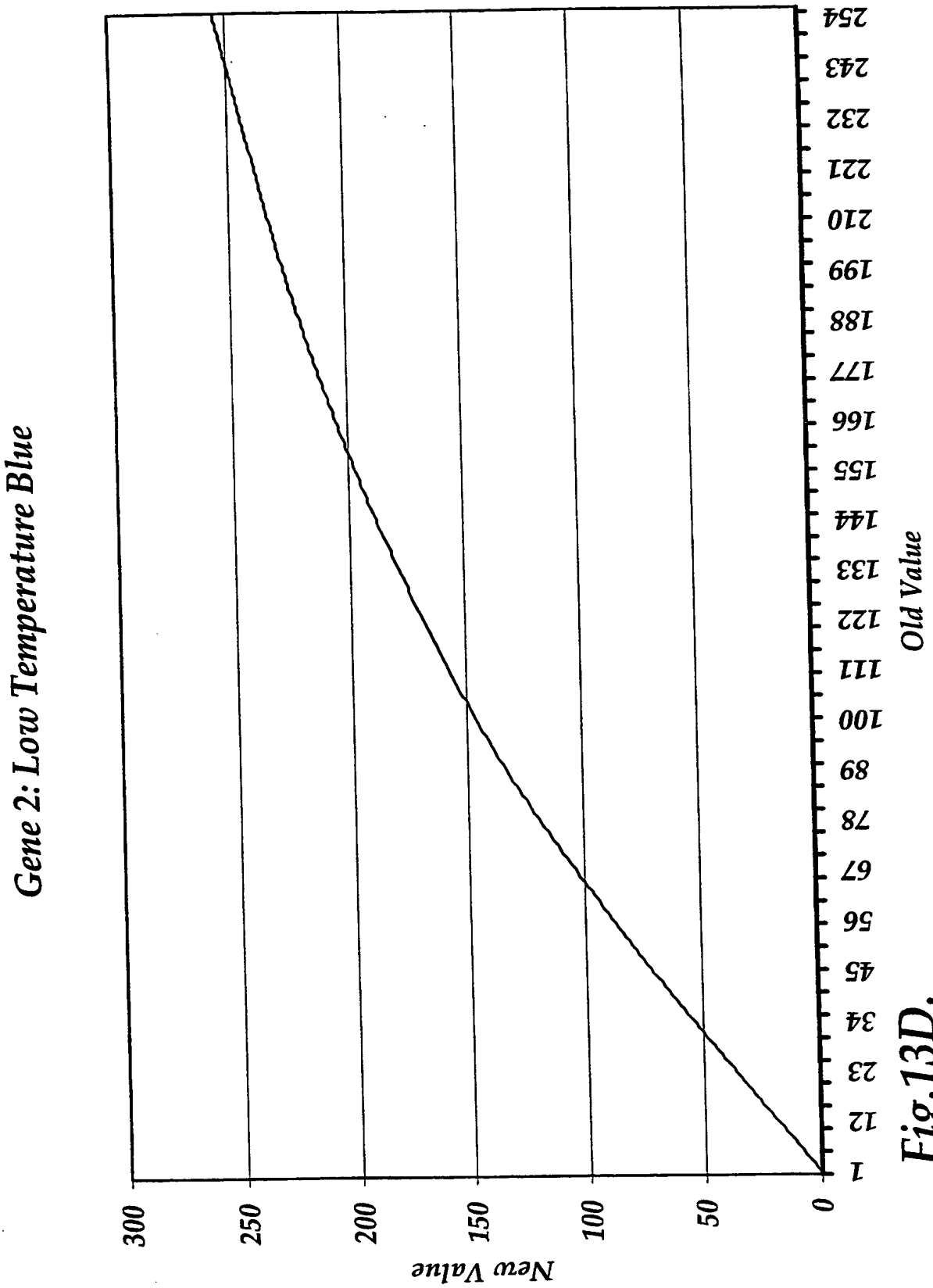

Gene 2: Low Temperature Blue
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.13D.

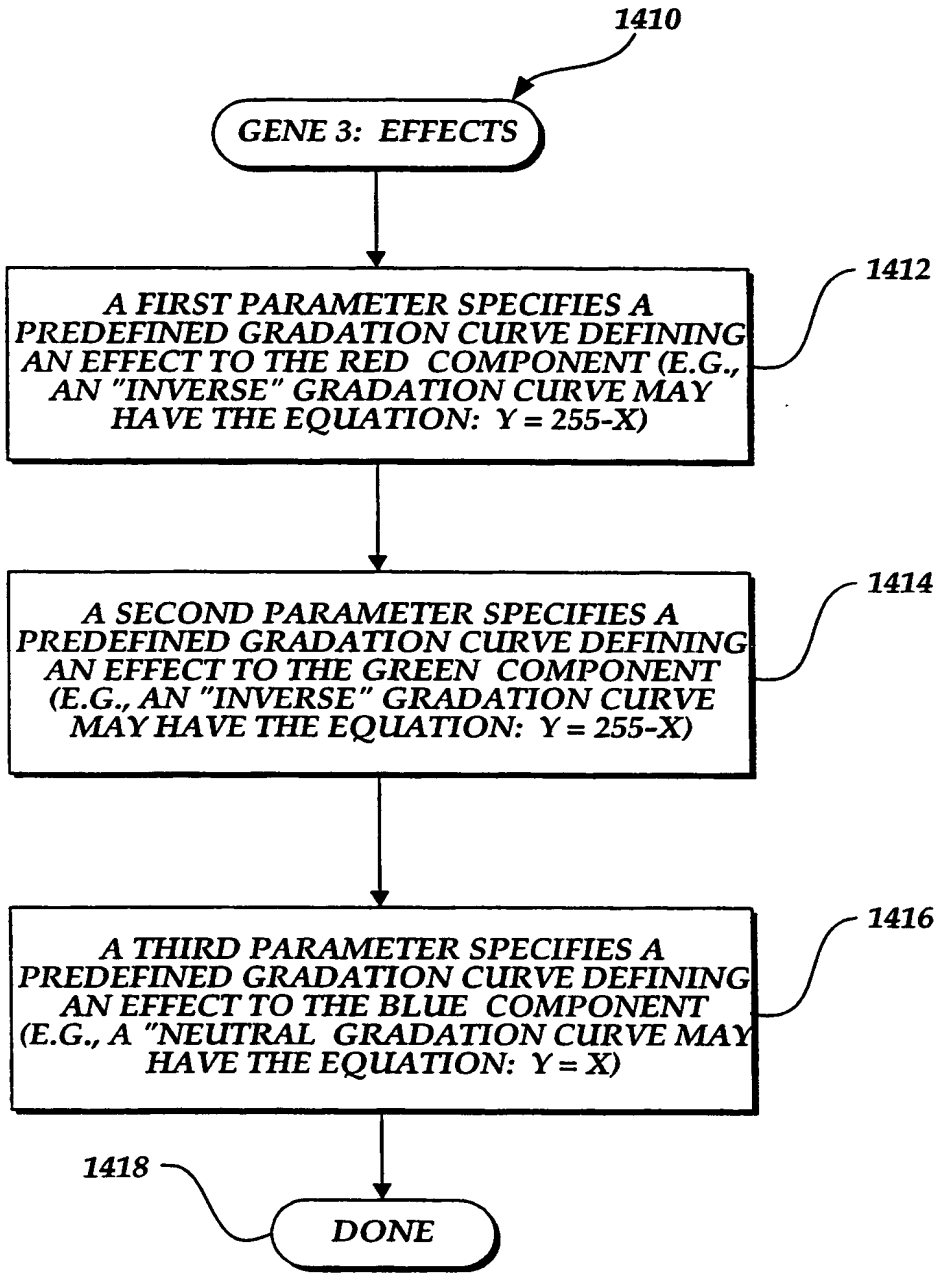

1410
GENE 3: EFFECTS
A FIRST PARAMETER SPECIFIES A PREDEFINED GRADATION CURVE DEFINING AN EFFECT TO THE RED COMPONENT (E.G., AN "INVERSE" GRADATION CURVE MAY HAVE THE EQUATION: Y = 255-X)
1412
A SECOND PARAMETER SPECIFIES A PREDEFINED GRADATION CURVE DEFINING AN EFFECT TO THE GREEN COMPONENT (E.G., AN "INVERSE" GRADATION CURVE MAY HAVE THE EQUATION: Y = 255-X)
1414
A THIRD PARAMETER SPECIFIES A PREDEFINED GRADATION CURVE DEFINING AN EFFECT TO THE BLUE COMPONENT (E.G., A "NEUTRAL GRADATION CURVE MAY HAVE THE EQUATION: Y = X)
1416
1418
DONE

Fig.14.

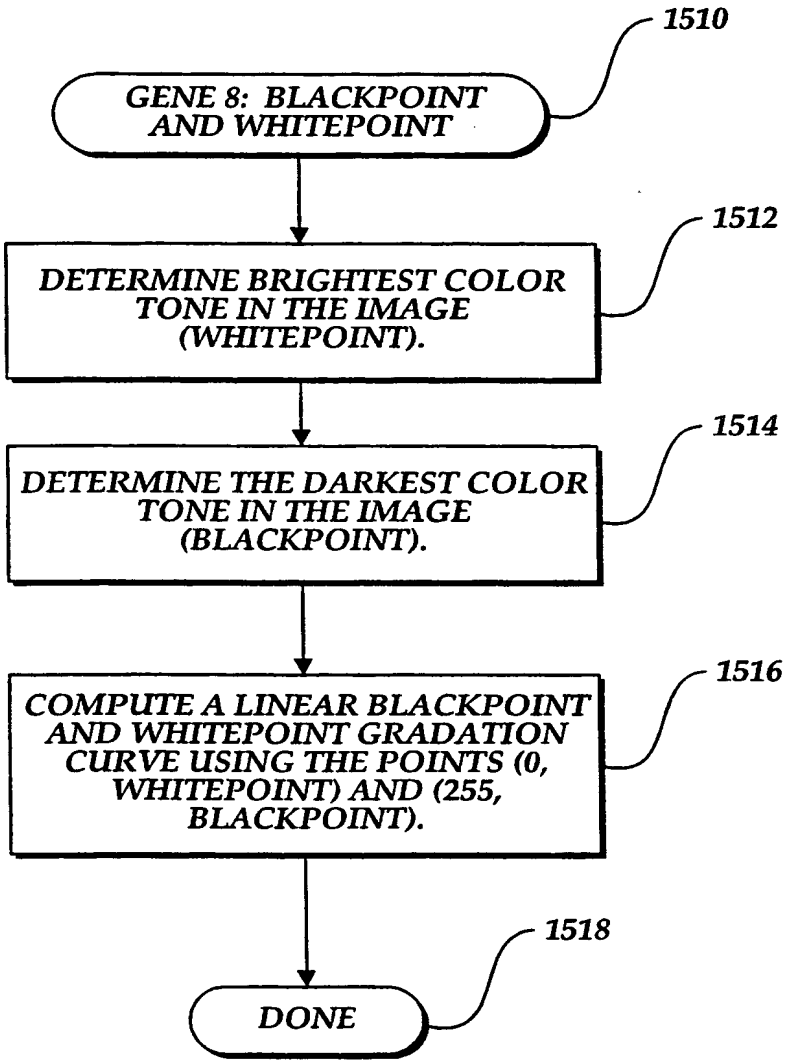

1510
GENE 8: BLACKPOINT AND WHITEPOINT
1512
DETERMINE BRIGHTEST COLOR TONE IN THE IMAGE (WHITEPOINT).
1514
DETERMINE THE DARKEST COLOR TONE IN THE IMAGE (BLACKPOINT).
1516
COMPUTE A LINEAR BLACKPOINT AND WHITEPOINT GRADATION CURVE USING THE POINTS (0, WHITEPOINT) AND (255, BLACKPOINT).
1518
DONE

Fig.15A.

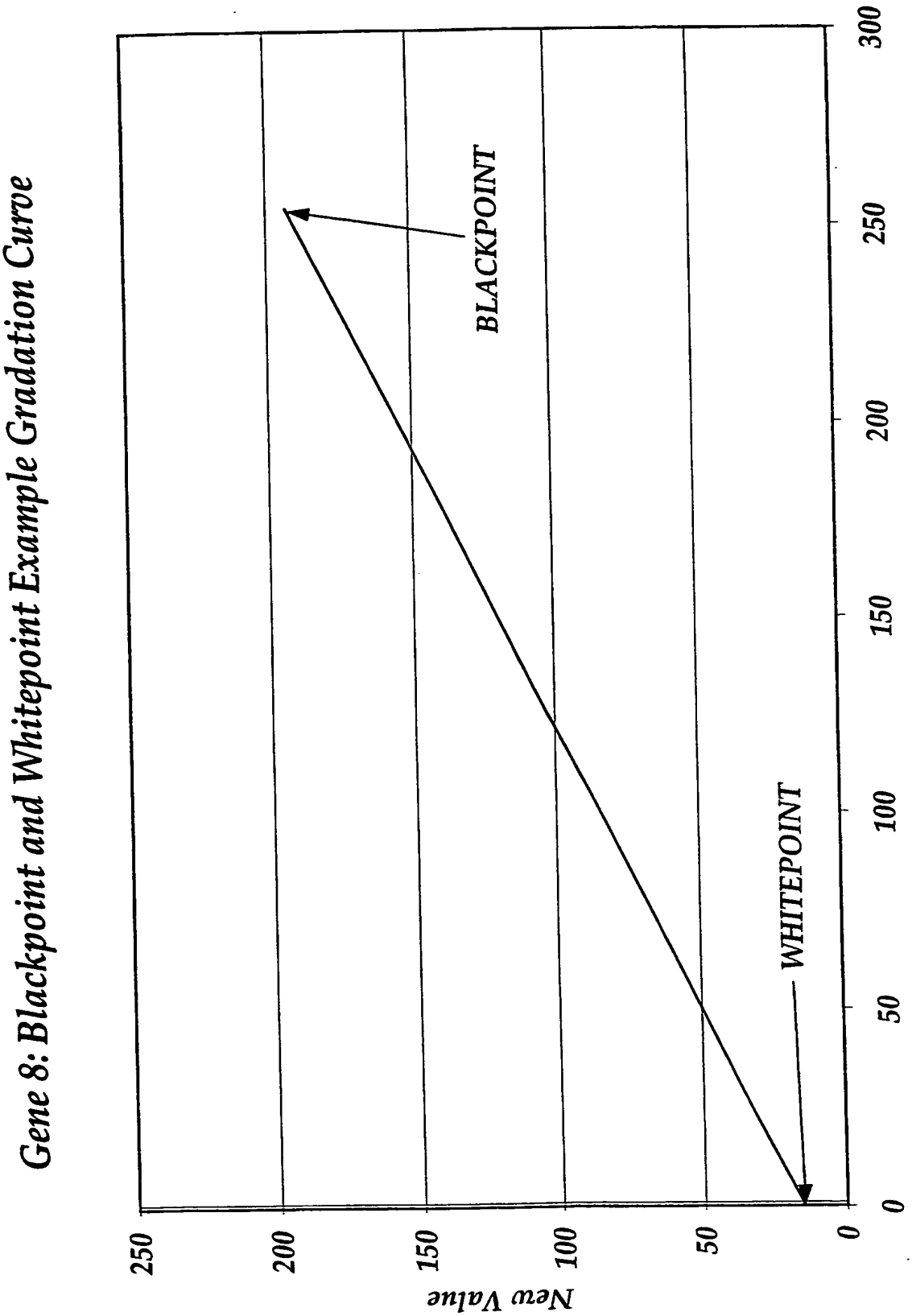

Gene 8: Blackpoint and Whitepoint Example Gradation Curve
BLACKPOINT
WHITEPOINT
New Value
Old Value
0
50
100
150
200
250
300

Fig.15B.

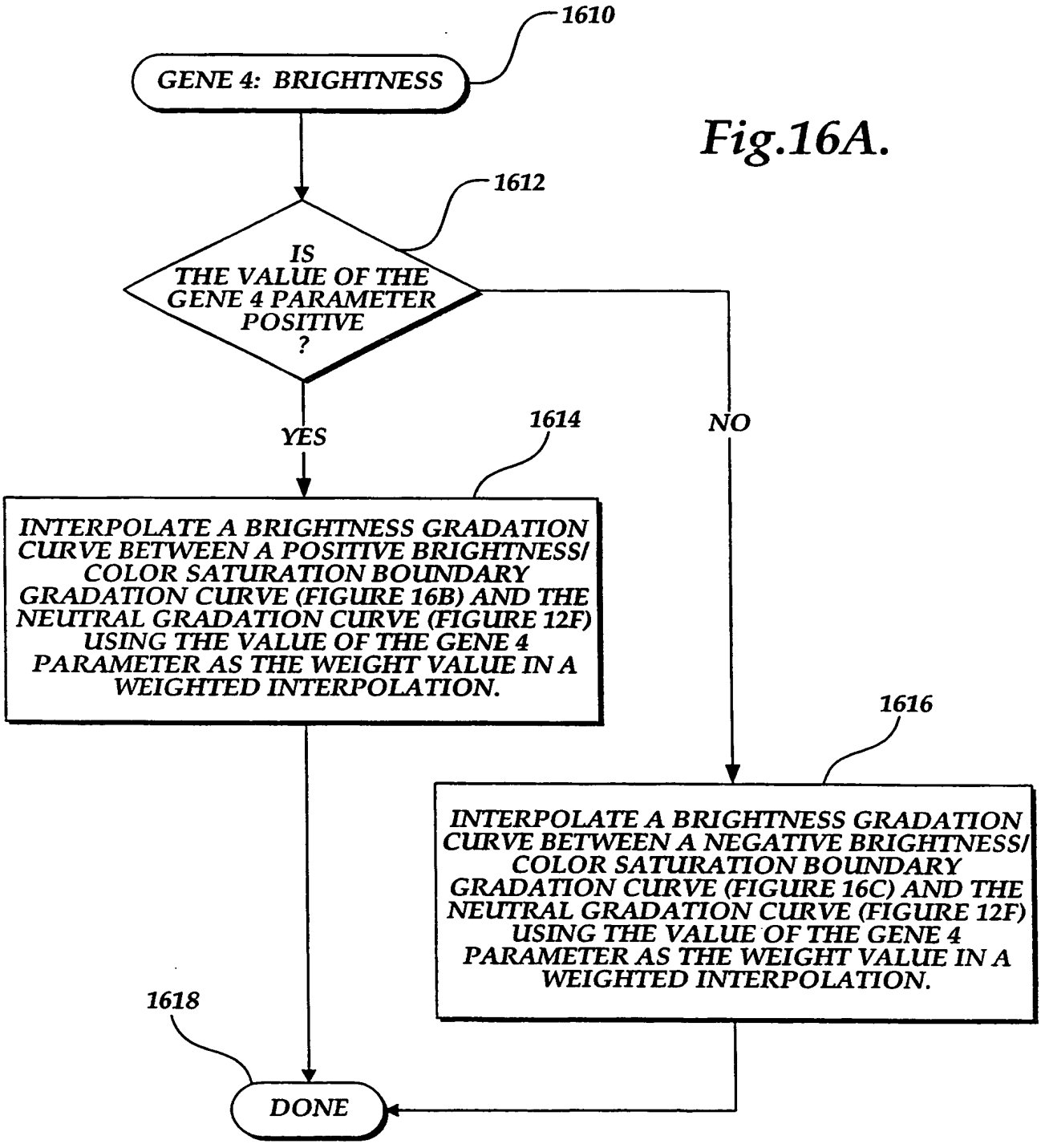

1610
GENE 4: BRIGHTNESS
1612
IS THE VALUE OF THE GENE 4 PARAMETER POSITIVE ?
YES
NO
1614
INTERPOLATE A BRIGHTNESS GRADATION CURVE BETWEEN A POSITIVE BRIGHTNESS/ COLOR SATURATION BOUNDARY GRADATION CURVE (FIGURE 16B) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F) USING THE VALUE OF THE GENE 4 PARAMETER AS THE WEIGHT VALUE IN A WEIGHTED INTERPOLATION.
1616
INTERPOLATE A BRIGHTNESS GRADATION CURVE BETWEEN A NEGATIVE BRIGHTNESS/ COLOR SATURATION BOUNDARY GRADATION CURVE (FIGURE 16C) AND THE NEUTRAL GRADATION CURVE (FIGURE 12F) USING THE VALUE OF THE GENE 4 PARAMETER AS THE WEIGHT VALUE IN A WEIGHTED INTERPOLATION.
1618
DONE

Fig.16A.

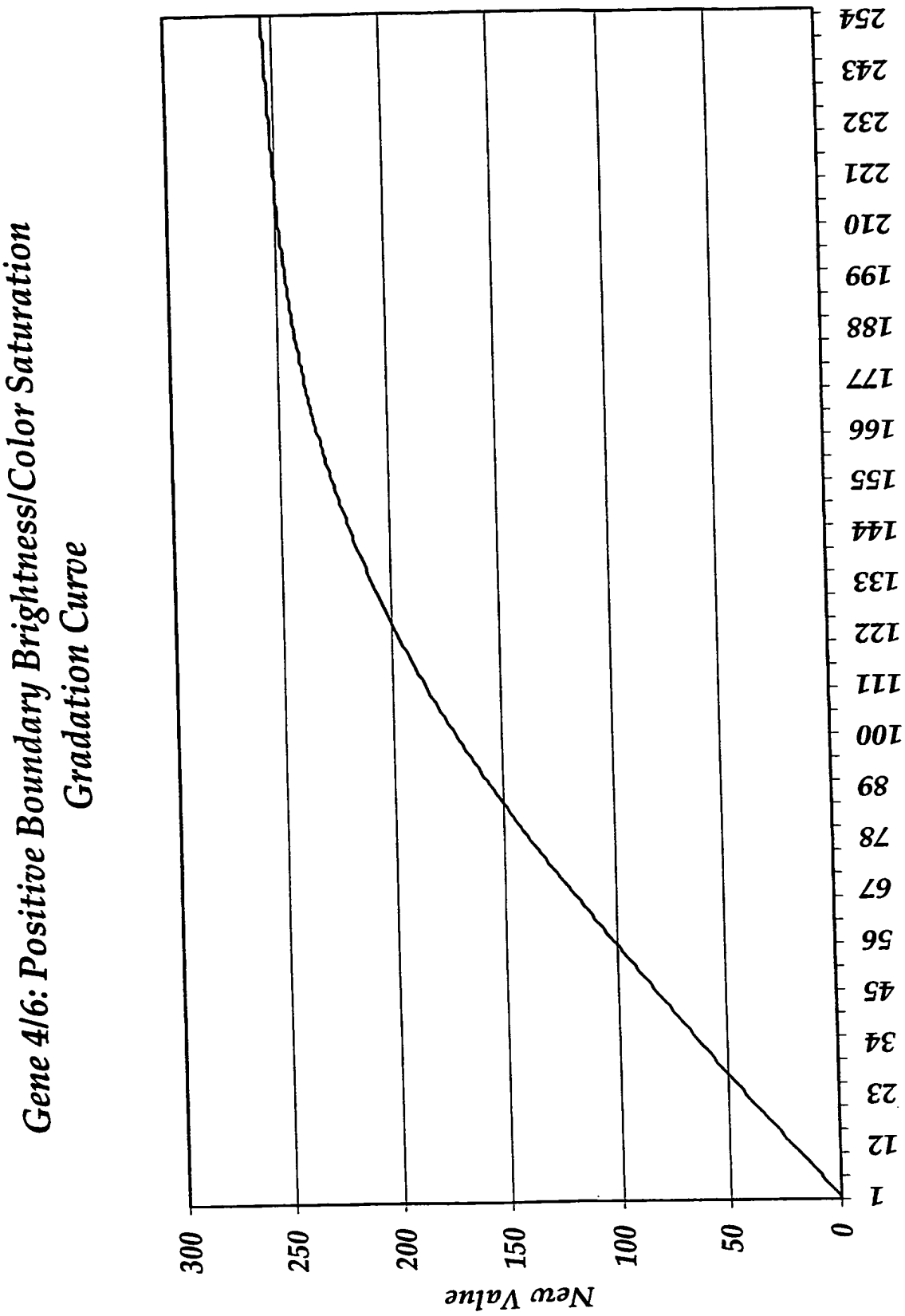

Gene 4/6: Positive Boundary Brightness/Color Saturation
Gradation Curve
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.16B.

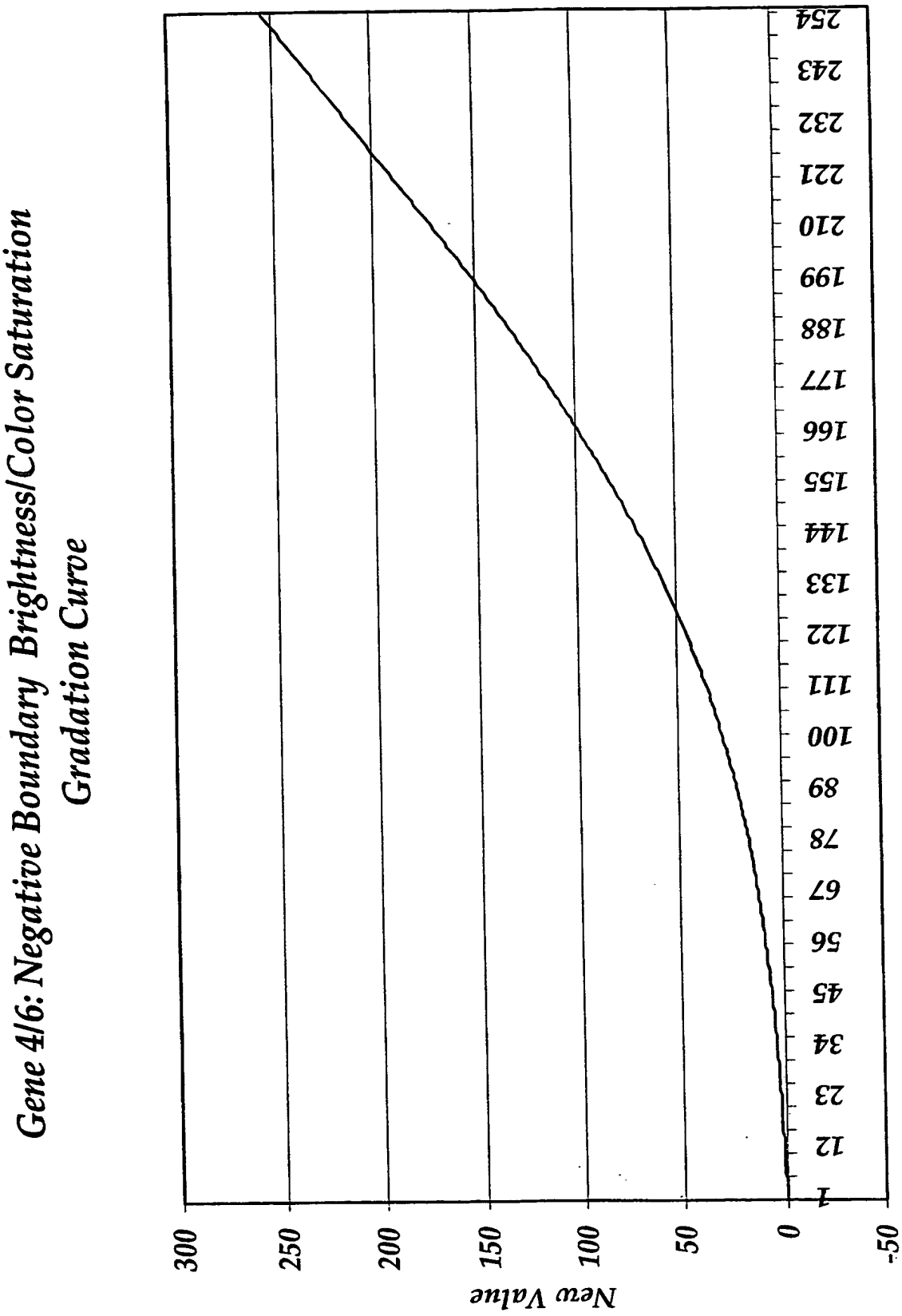

Gene 4/6: Negative Boundary Brightness/Color Saturation
Gradation Curve
New Value
300
250
200
150
100
50
0
-50
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.16C.

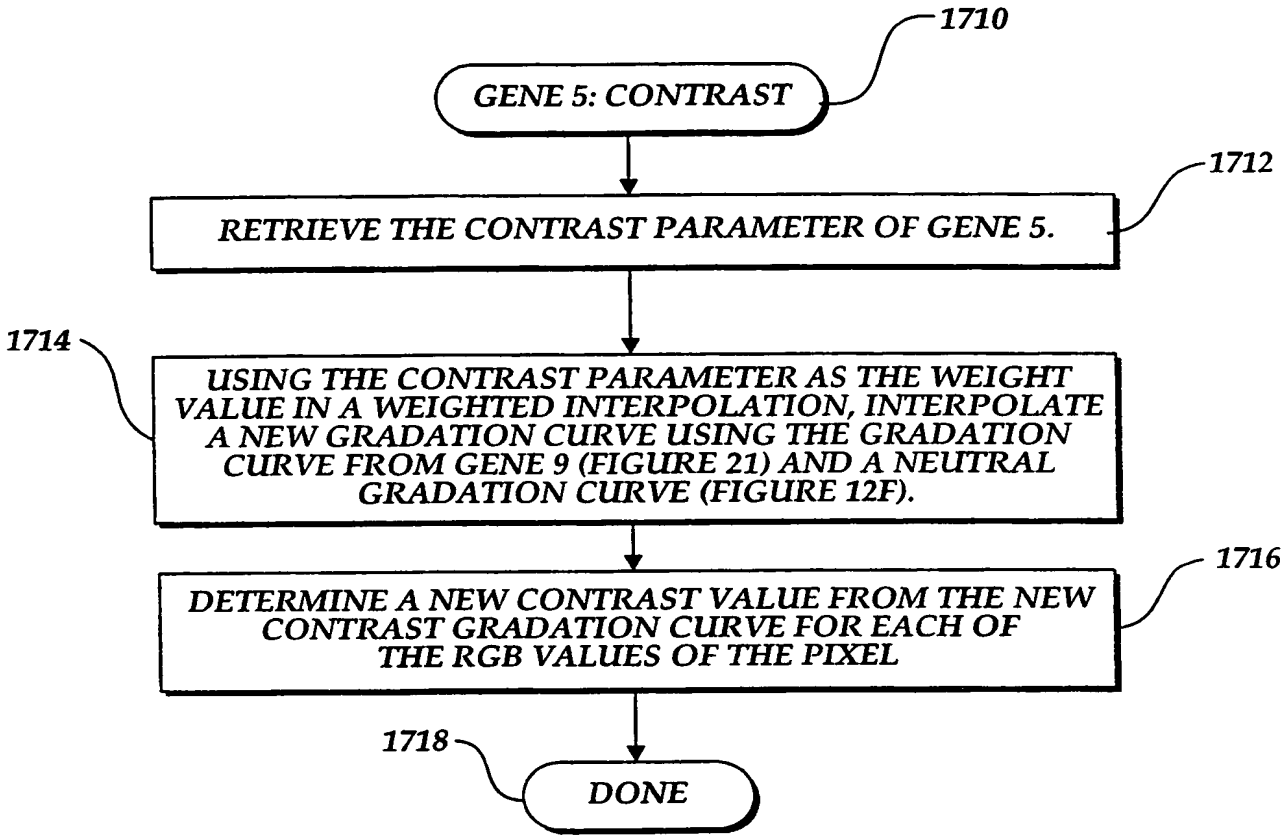

1710
GENE 5: CONTRAST
1712
RETRIEVE THE CONTRAST PARAMETER OF GENE 5.
1714
USING THE CONTRAST PARAMETER AS THE WEIGHT VALUE IN A WEIGHTED INTERPOLATION, INTERPOLATE A NEW GRADATION CURVE USING THE GRADATION CURVE FROM GENE 9 (FIGURE 21) AND A NEUTRAL GRADATION CURVE (FIGURE 12F).
1716
DETERMINE A NEW CONTRAST VALUE FROM THE NEW CONTRAST GRADATION CURVE FOR EACH OF THE RGB VALUES OF THE PIXEL
1718
DONE

Fig.17.

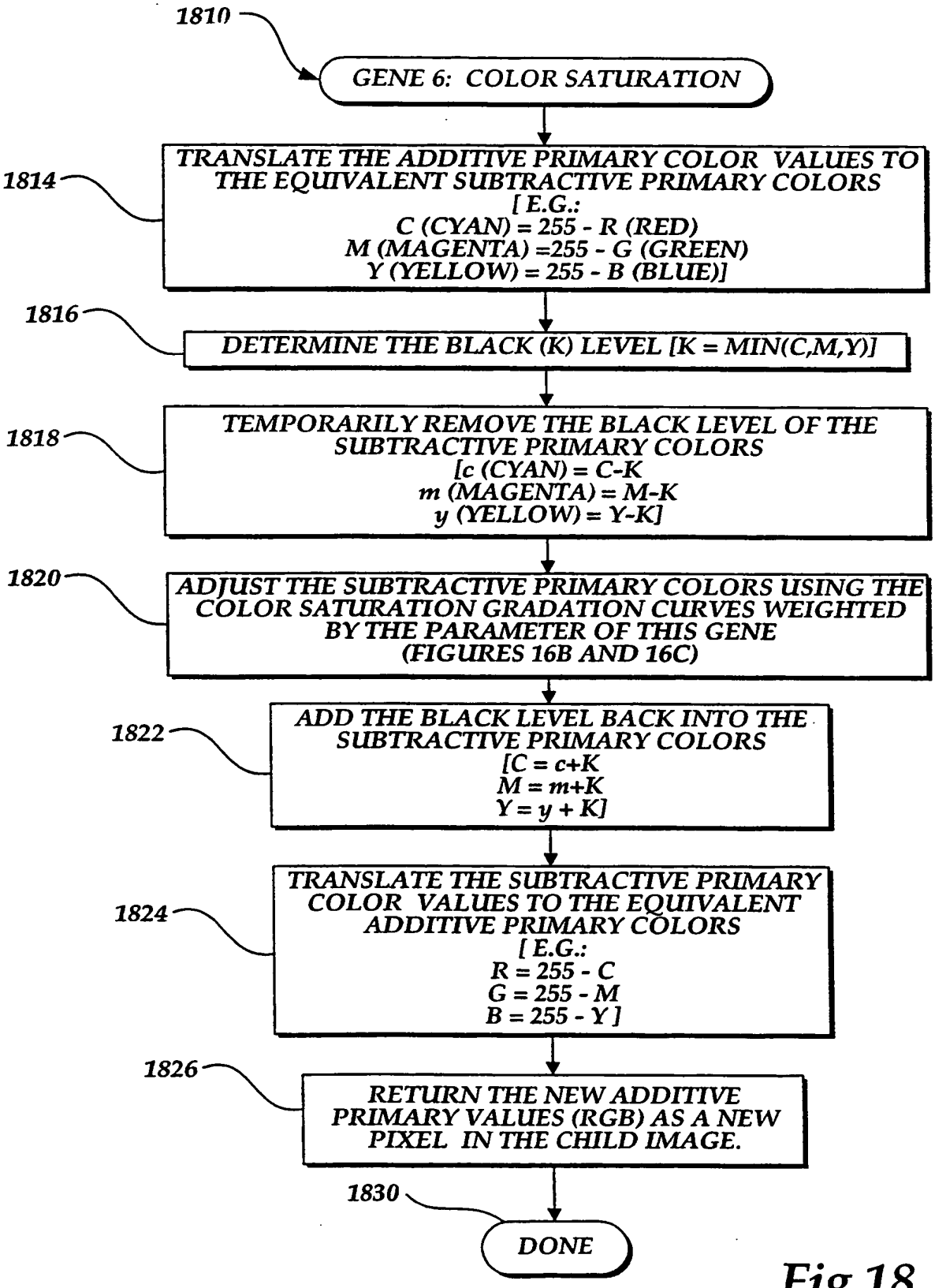

1810
GENE 6: COLOR SATURATION
1814
TRANSLATE THE ADDITIVE PRIMARY COLOR VALUES TO THE EQUIVALENT SUBTRACTIVE PRIMARY COLORS
[E.G.:
C (CYAN) = 255 - R (RED)
M (MAGENTA) =255 - G (GREEN)
Y (YELLOW) = 255 - B (BLUE)]
1816
DETERMINE THE BLACK (K) LEVEL [K = MIN(C,M,Y)]
1818
TEMPORARILY REMOVE THE BLACK LEVEL OF THE SUBTRACTIVE PRIMARY COLORS
[c (CYAN) = C-K
m (MAGENTA) = M-K
y (YELLOW) = Y-K]
1820
ADJUST THE SUBTRACTIVE PRIMARY COLORS USING THE COLOR SATURATION GRADATION CURVES WEIGHTED BY THE PARAMETER OF THIS GENE
(FIGURES 16B AND 16C)
1822
ADD THE BLACK LEVEL BACK INTO THE SUBTRACTIVE PRIMARY COLORS
[C = c+K
M = m+K
Y = y + K]
1824
TRANSLATE THE SUBTRACTIVE PRIMARY COLOR VALUES TO THE EQUIVALENT ADDITIVE PRIMARY COLORS
[E.G.:
R = 255 - C
G = 255 - M
B = 255 - Y]
1826
RETURN THE NEW ADDITIVE PRIMARY VALUES (RGB) AS A NEW PIXEL IN THE CHILD IMAGE.
1830
DONE

Fig.18.

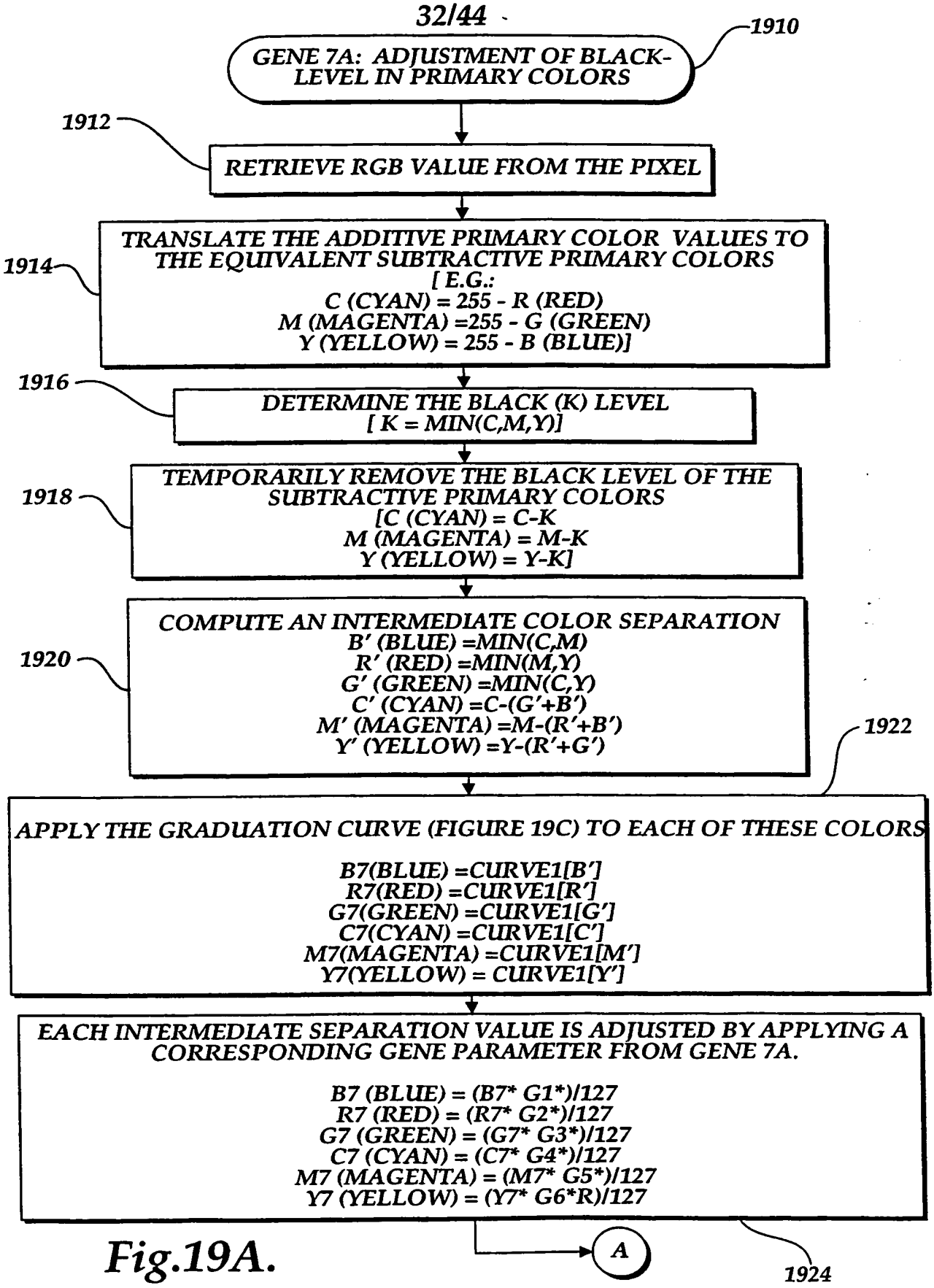

GENE 7A: ADJUSTMENT OF BLACK-LEVEL IN PRIMARY COLORS
1910
1912
RETRIEVE RGB VALUE FROM THE PIXEL
TRANSLATE THE ADDITIVE PRIMARY COLOR VALUES TO THE EQUIVALENT SUBTRACTIVE PRIMARY COLORS
[E.G.:
C (CYAN) = 255 - R (RED)
M (MAGENTA) =255 - G (GREEN)
Y (YELLOW) = 255 - B (BLUE)]
1914
1916
DETERMINE THE BLACK (K) LEVEL
[K = MIN(C,M,Y)]
TEMPORARILY REMOVE THE BLACK LEVEL OF THE SUBTRACTIVE PRIMARY COLORS
[C (CYAN) = C-K
M (MAGENTA) = M-K
Y (YELLOW) = Y-K]
1918
COMPUTE AN INTERMEDIATE COLOR SEPARATION
B' (BLUE) =MIN(C,M)
R' (RED) =MIN(M,Y)
G' (GREEN) =MIN(C,Y)
C' (CYAN) =C-(G'+B')
M' (MAGENTA) =M-(R'+B')
Y' (YELLOW) =Y-(R'+G')
1920
1922
APPLY THE GRADUATION CURVE (FIGURE 19C) TO EACH OF THESE COLORS
B7(BLUE) =CURVE1[B']
R7(RED) =CURVE1[R']
G7(GREEN) =CURVE1[G']
C7(CYAN) =CURVE1[C']
M7(MAGENTA) =CURVE1[M']
Y7(YELLOW) = CURVE1[Y']
EACH INTERMEDIATE SEPARATION VALUE IS ADJUSTED BY APPLYING A CORRESPONDING GENE PARAMETER FROM GENE 7A.
B7 (BLUE) = (B7* G1*)/127
R7 (RED) = (R7* G2*)/127
G7 (GREEN) = (G7* G3*)/127
C7 (CYAN) = (C7* G4*)/127
M7 (MAGENTA) = (M7* G5*)/127
Y7 (YELLOW) = (Y7* G6*R)/127
A
1924

Fig.19A.

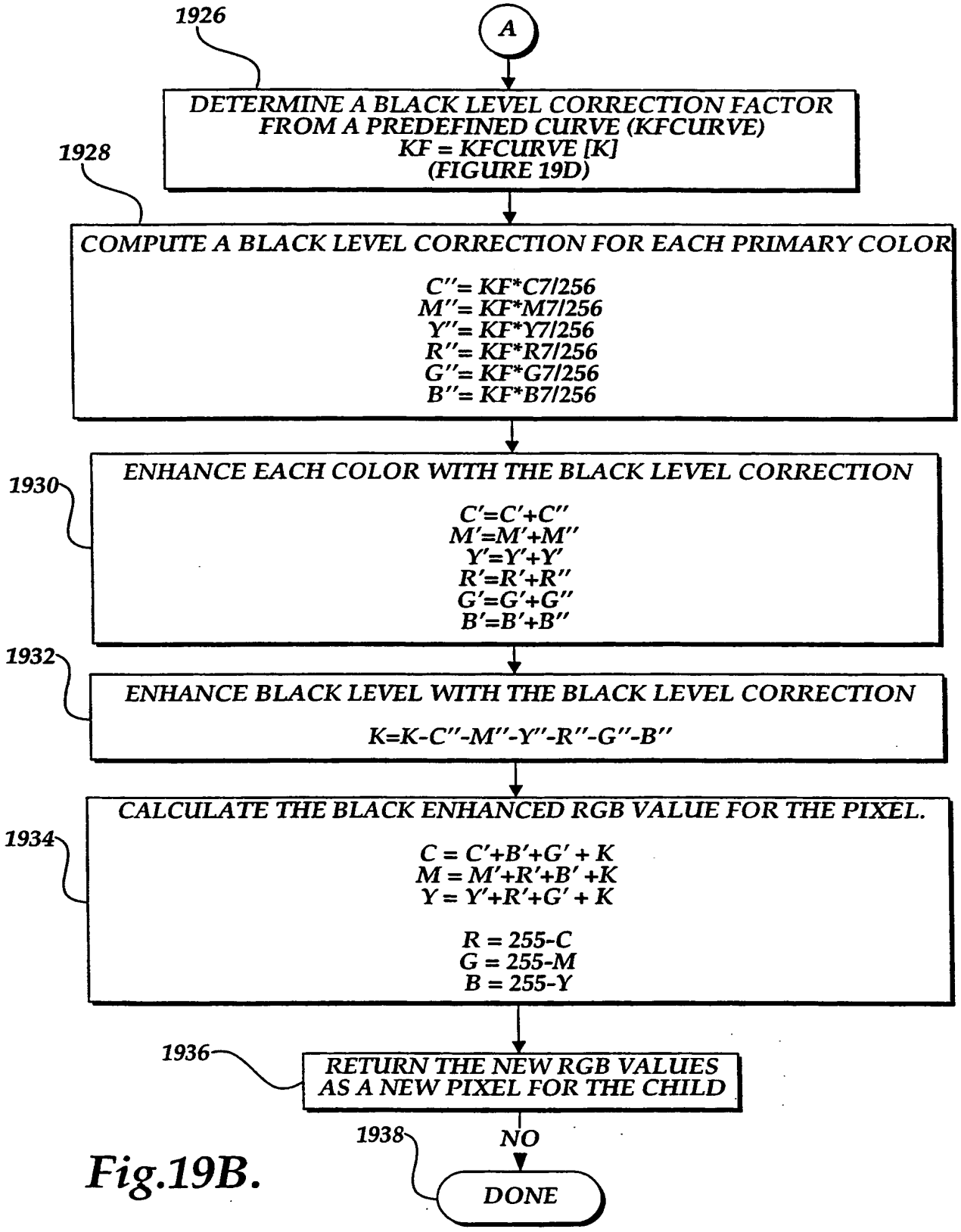

A
1926
DETERMINE A BLACK LEVEL CORRECTION FACTOR FROM A PREDEFINED CURVE (KFCURVE)
KF = KFCURVE [K]
(FIGURE 19D)
1928
COMPUTE A BLACK LEVEL CORRECTION FOR EACH PRIMARY COLOR
C''= KF*C7/256
M''= KF*M7/256
Y''= KF*Y7/256
R''= KF*R7/256
G''= KF*G7/256
B''= KF*B7/256
1930
ENHANCE EACH COLOR WITH THE BLACK LEVEL CORRECTION
C'=C'+C''
M'=M'+M''
Y'=Y'+Y'
R'=R'+R''
G'=G'+G''
B'=B'+B''
1932
ENHANCE BLACK LEVEL WITH THE BLACK LEVEL CORRECTION
K=K-C''-M''-Y''-R''-G''-B''
1934
CALCULATE THE BLACK ENHANCED RGB VALUE FOR THE PIXEL.
C = C'+B'+G' + K
M = M'+R'+B' +K
Y = Y'+R'+G' + K
R = 255-C
G = 255-M
B = 255-Y
1936
RETURN THE NEW RGB VALUES AS A NEW PIXEL FOR THE CHILD
1938
NO
DONE

Fig.19B.

Gene 7a
New Value
0
10
20
30
40
50
60
70
80
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.19C.

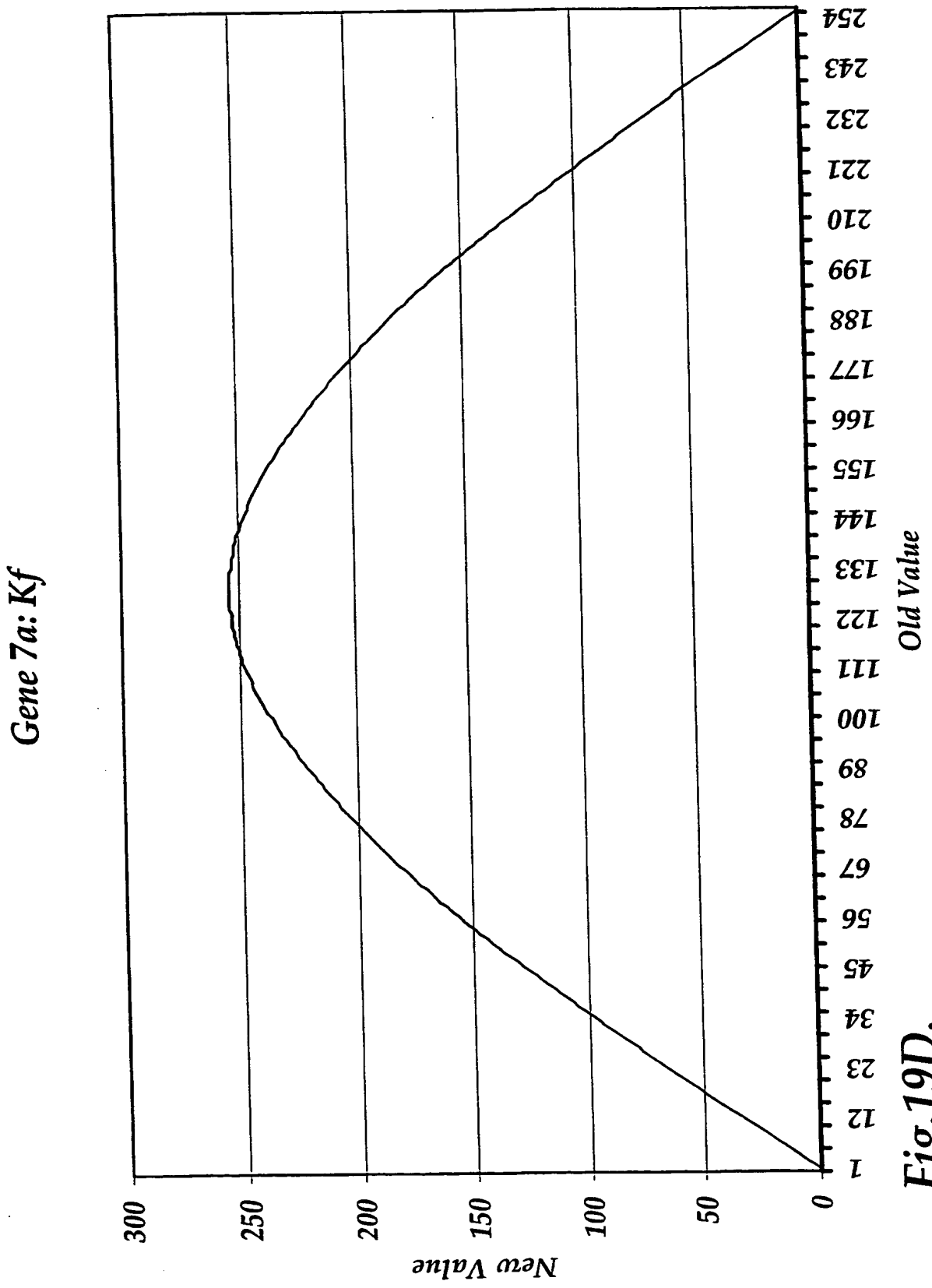

Gene 7a: Kf
New Value
300
250
200
150
100
50
0
Old Value
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
199
210
221
232
243
254

Fig.19D.

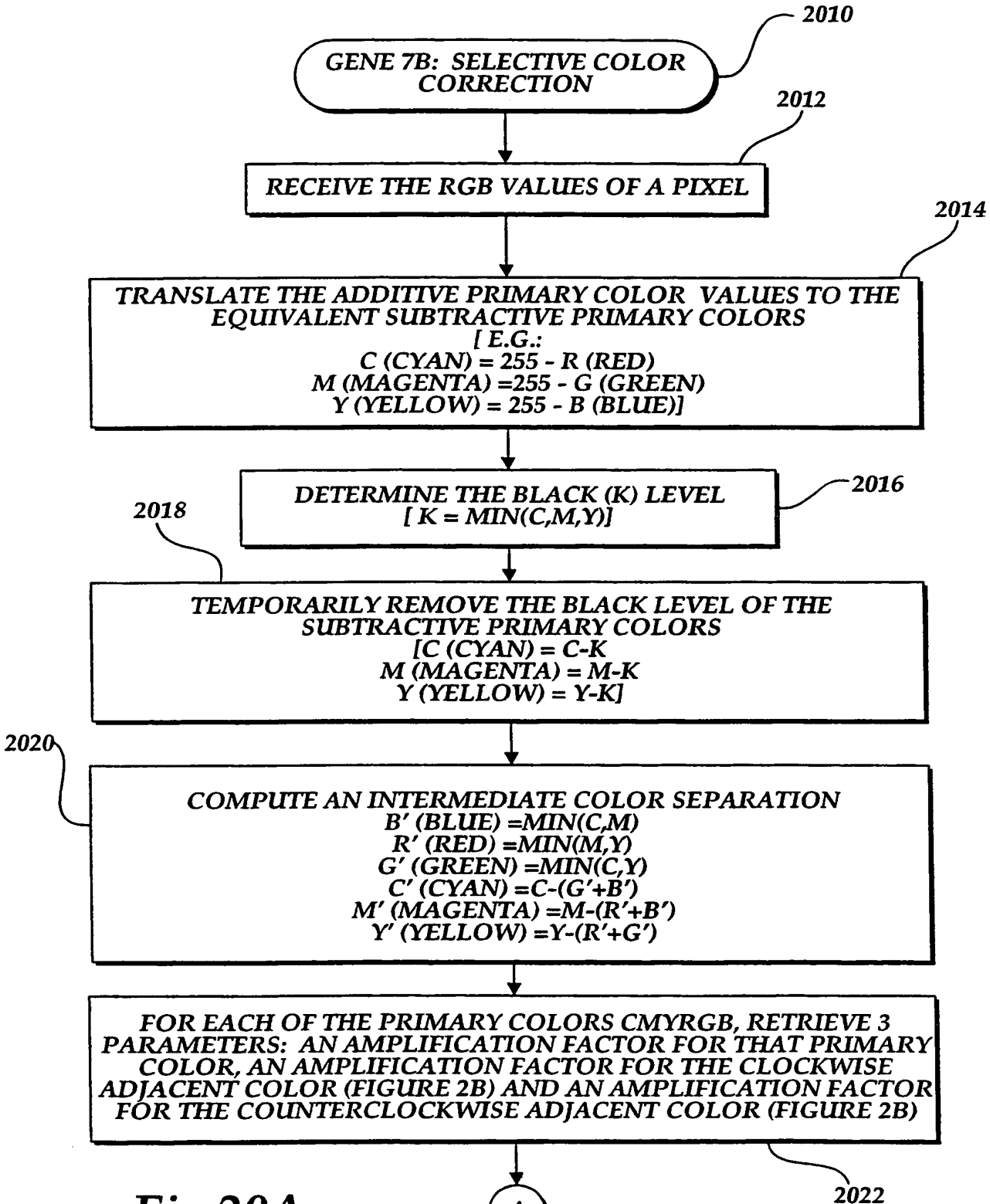

2010
GENE 7B: SELECTIVE COLOR CORRECTION
2012
RECEIVE THE RGB VALUES OF A PIXEL
2014
TRANSLATE THE ADDITIVE PRIMARY COLOR VALUES TO THE EQUIVALENT SUBTRACTIVE PRIMARY COLORS
[E.G.:
C (CYAN) = 255 - R (RED)
M (MAGENTA) =255 - G (GREEN)
Y (YELLOW) = 255 - B (BLUE)]
2016
DETERMINE THE BLACK (K) LEVEL
[K = MIN(C,M,Y)]
2018
TEMPORARILY REMOVE THE BLACK LEVEL OF THE SUBTRACTIVE PRIMARY COLORS
[C (CYAN) = C-K
M (MAGENTA) = M-K
Y (YELLOW) = Y-K]
2020
COMPUTE AN INTERMEDIATE COLOR SEPARATION
B' (BLUE) =MIN(C,M)
R' (RED) =MIN(M,Y)
G' (GREEN) =MIN(C,Y)
C' (CYAN) =C-(G'+B')
M' (MAGENTA) =M-(R'+B')
Y' (YELLOW) =Y-(R'+G')
FOR EACH OF THE PRIMARY COLORS CMYRGB, RETRIEVE 3 PARAMETERS: AN AMPLIFICATION FACTOR FOR THAT PRIMARY COLOR, AN AMPLIFICATION FACTOR FOR THE CLOCKWISE ADJACENT COLOR (FIGURE 2B) AND AN AMPLIFICATION FACTOR FOR THE COUNTERCLOCKWISE ADJACENT COLOR (FIGURE 2B)
2022
A

Fig.20A.

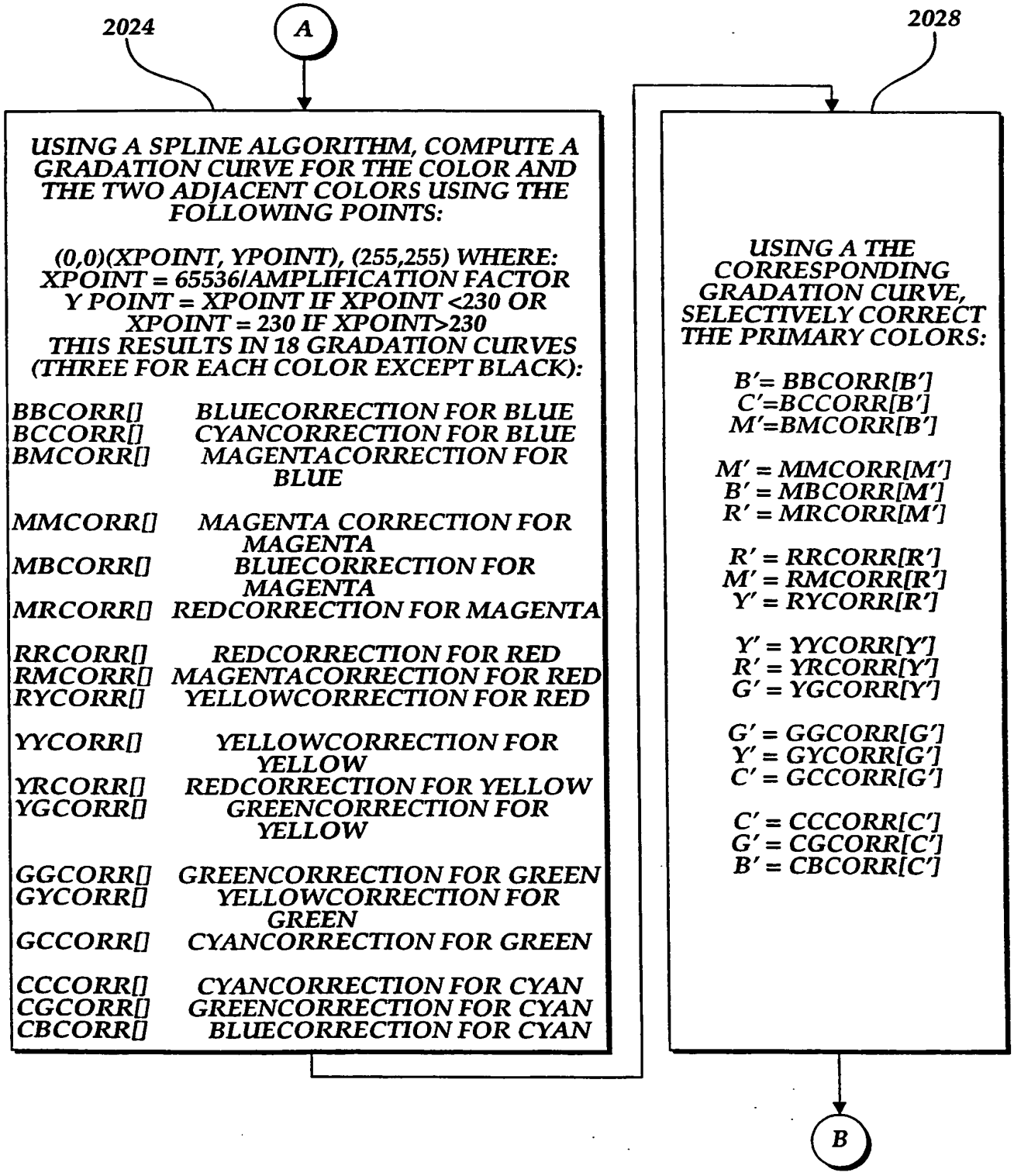

2024
A
USING A SPLINE ALGORITHM, COMPUTE A GRADATION CURVE FOR THE COLOR AND THE TWO ADJACENT COLORS USING THE FOLLOWING POINTS:
(0,0)(XPOINT, YPOINT), (255,255) WHERE:
XPOINT = 65536/AMPLIFICATION FACTOR
Y POINT = XPOINT IF XPOINT <230 OR
XPOINT = 230 IF XPOINT>230
THIS RESULTS IN 18 GRADATION CURVES (THREE FOR EACH COLOR EXCEPT BLACK):
BBCORR[] BLUECORRECTION FOR BLUE
BCCORR[] CYANCORRECTION FOR BLUE
BMCORR[] MAGENTACORRECTION FOR BLUE
MMCORR[] MAGENTA CORRECTION FOR MAGENTA
MBCORR[] BLUECORRECTION FOR MAGENTA
MRCORR[] REDCORRECTION FOR MAGENTA
RRCORR[] REDCORRECTION FOR RED
RMCORR[] MAGENTACORRECTION FOR RED
RYCORR[] YELLOWCORRECTION FOR RED
YYCORR[] YELLOWCORRECTION FOR YELLOW
YRCORR[] REDCORRECTION FOR YELLOW
YGCORR[] GREENCORRECTION FOR YELLOW
GGCORR[] GREENCORRECTION FOR GREEN
GYCORR[] YELLOWCORRECTION FOR GREEN
GCCORR[] CYANCORRECTION FOR GREEN
CCCORR[] CYANCORRECTION FOR CYAN
CGCORR[] GREENCORRECTION FOR CYAN
CBCORR[] BLUECORRECTION FOR CYAN
2028
USING A THE CORRESPONDING GRADATION CURVE, SELECTIVELY CORRECT THE PRIMARY COLORS:
B'= BBCORR[B']
C'=BCCORR[B']
M'=BMCORR[B']
M' = MMCORR[M']
B' = MBCORR[M']
R' = MRCORR[M']
R' = RRCORR[R']
M' = RMCORR[R']
Y' = RYCORR[R']
Y' = YYCORR[Y']
R' = YRCORR[Y']
G' = YGCORR[Y']
G' = GGCORR[G']
Y' = GYCORR[G']
C' = GCCORR[G']
C' = CCCORR[C']
G' = CGCORR[C']
B' = CBCORR[C']
B

Fig.20B.

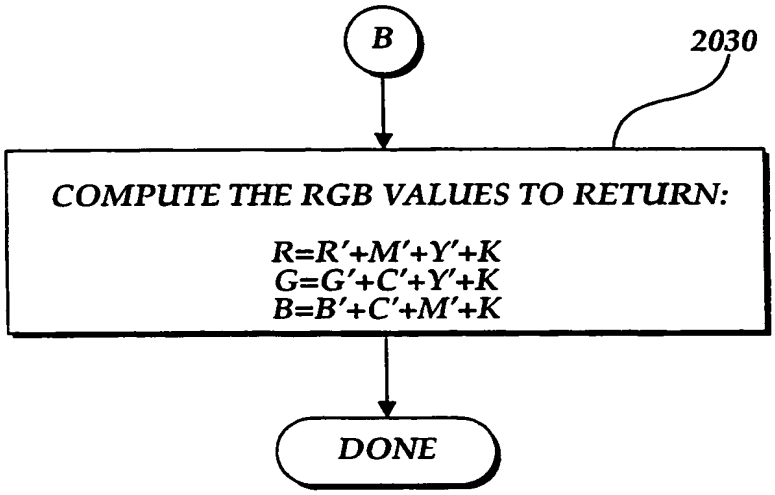

B
2030
COMPUTE THE RGB VALUES TO RETURN:
R=R'+M'+Y'+K
G=G'+C'+Y'+K
B=B'+C'+M'+K
DONE

Fig.20C.

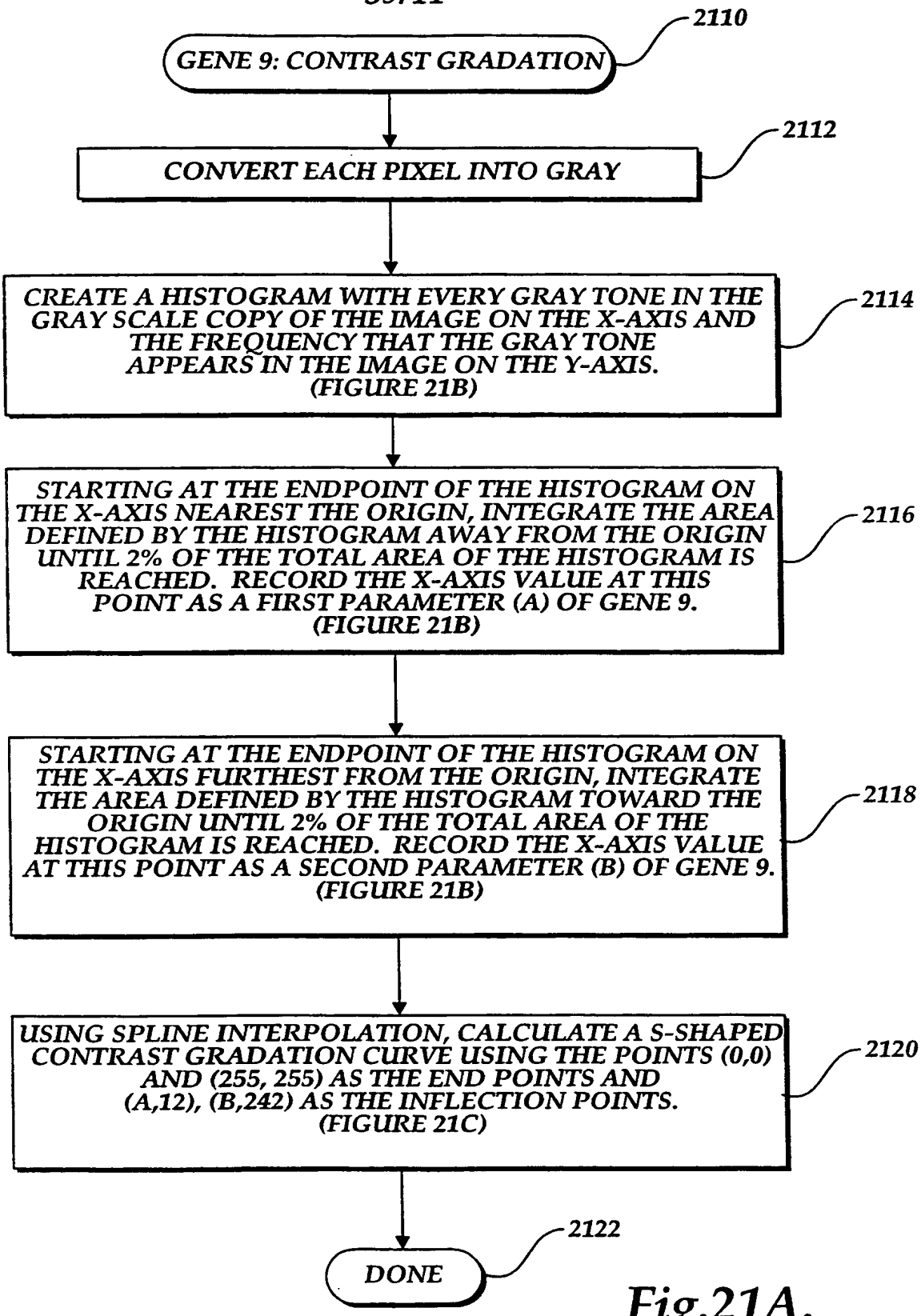

GENE 9: CONTRAST GRADATION
2110
CONVERT EACH PIXEL INTO GRAY
2112
CREATE A HISTOGRAM WITH EVERY GRAY TONE IN THE GRAY SCALE COPY OF THE IMAGE ON THE X-AXIS AND THE FREQUENCY THAT THE GRAY TONE APPEARS IN THE IMAGE ON THE Y-AXIS. (FIGURE 21B)
2114
STARTING AT THE ENDPOINT OF THE HISTOGRAM ON THE X-AXIS NEAREST THE ORIGIN, INTEGRATE THE AREA DEFINED BY THE HISTOGRAM AWAY FROM THE ORIGIN UNTIL 2% OF THE TOTAL AREA OF THE HISTOGRAM IS REACHED. RECORD THE X-AXIS VALUE AT THIS POINT AS A FIRST PARAMETER (A) OF GENE 9. (FIGURE 21B)
2116
STARTING AT THE ENDPOINT OF THE HISTOGRAM ON THE X-AXIS FURTHEST FROM THE ORIGIN, INTEGRATE THE AREA DEFINED BY THE HISTOGRAM TOWARD THE ORIGIN UNTIL 2% OF THE TOTAL AREA OF THE HISTOGRAM IS REACHED. RECORD THE X-AXIS VALUE AT THIS POINT AS A SECOND PARAMETER (B) OF GENE 9. (FIGURE 21B)
2118
USING SPLINE INTERPOLATION, CALCULATE A S-SHAPED CONTRAST GRADATION CURVE USING THE POINTS (0,0) AND (255, 255) AS THE END POINTS AND (A,12), (B,242) AS THE INFLECTION POINTS. (FIGURE 21C)
2120
DONE
2122

Fig.21A.

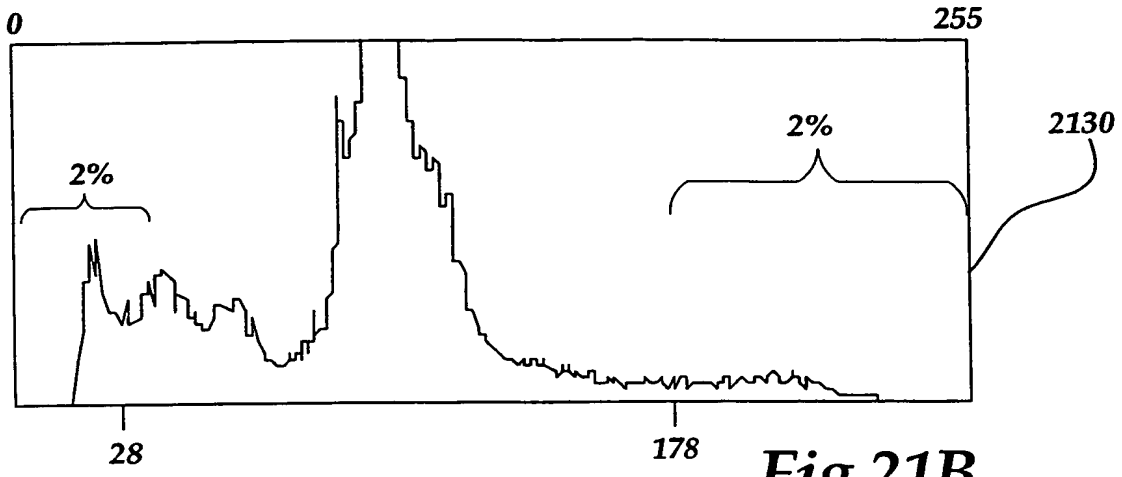


Fig.21B.

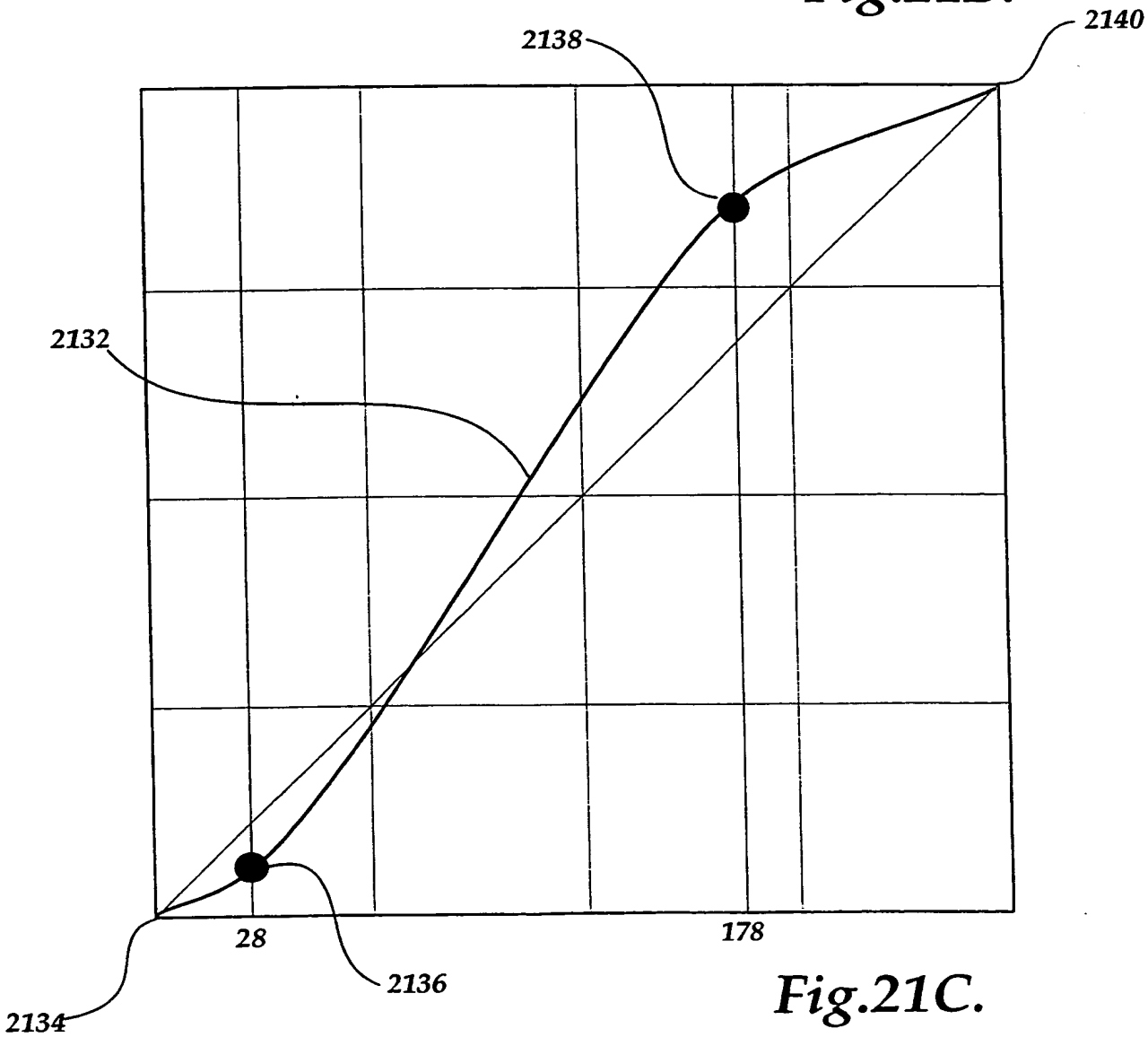


Fig.21C.

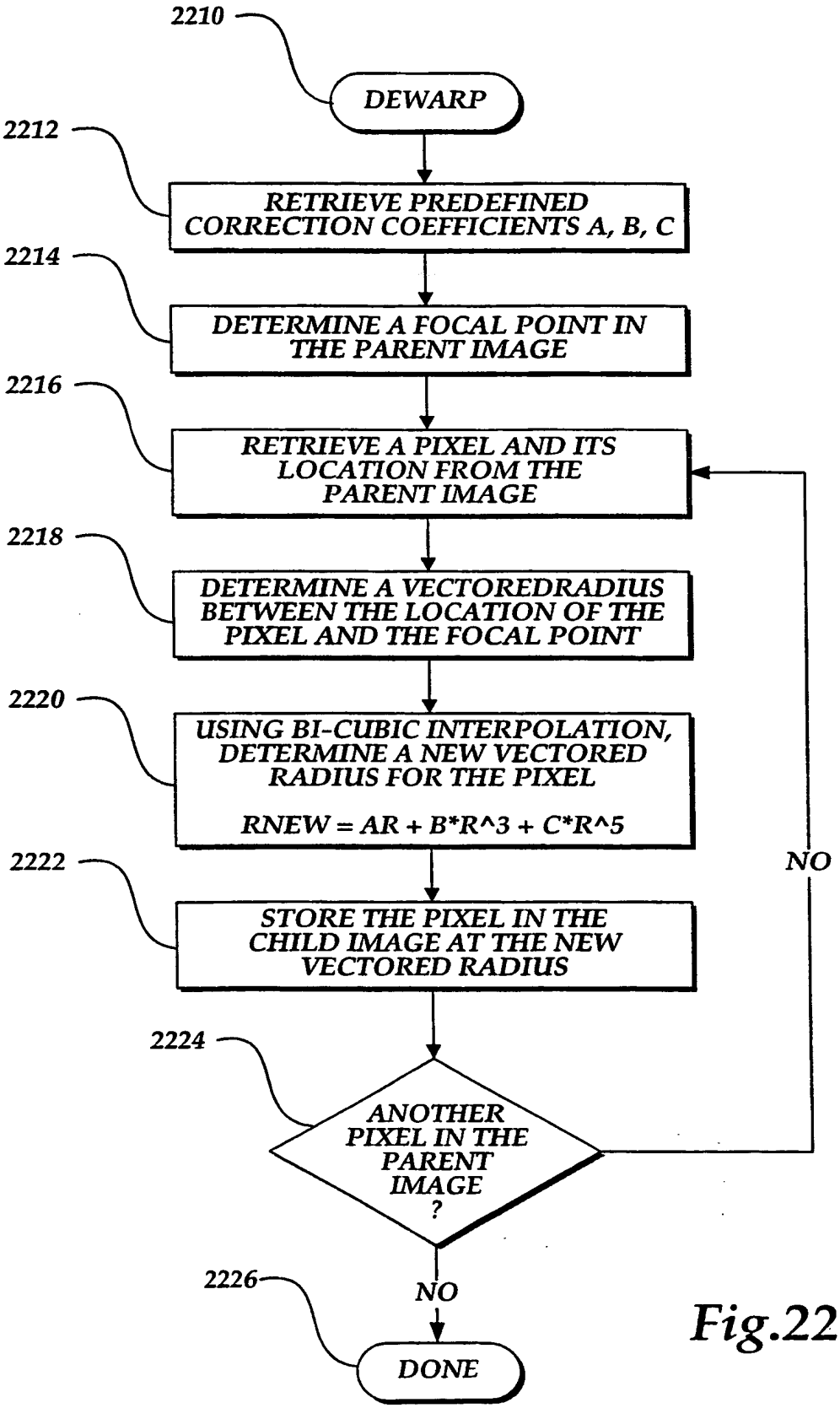

2210
DEWARP
2212
RETRIEVE PREDEFINED CORRECTION COEFFICIENTS A, B, C
2214
DETERMINE A FOCAL POINT IN THE PARENT IMAGE
2216
RETRIEVE A PIXEL AND ITS LOCATION FROM THE PARENT IMAGE
2218
DETERMINE A VECTOREDRADIUS BETWEEN THE LOCATION OF THE PIXEL AND THE FOCAL POINT
2220
USING BI-CUBIC INTERPOLATION, DETERMINE A NEW VECTORED RADIUS FOR THE PIXEL
RNEW = AR + B*R^3 + C*R^5
2222
STORE THE PIXEL IN THE CHILD IMAGE AT THE NEW VECTORED RADIUS
2224
ANOTHER PIXEL IN THE PARENT IMAGE ?
NO
NO
2226
DONE

Fig.22.

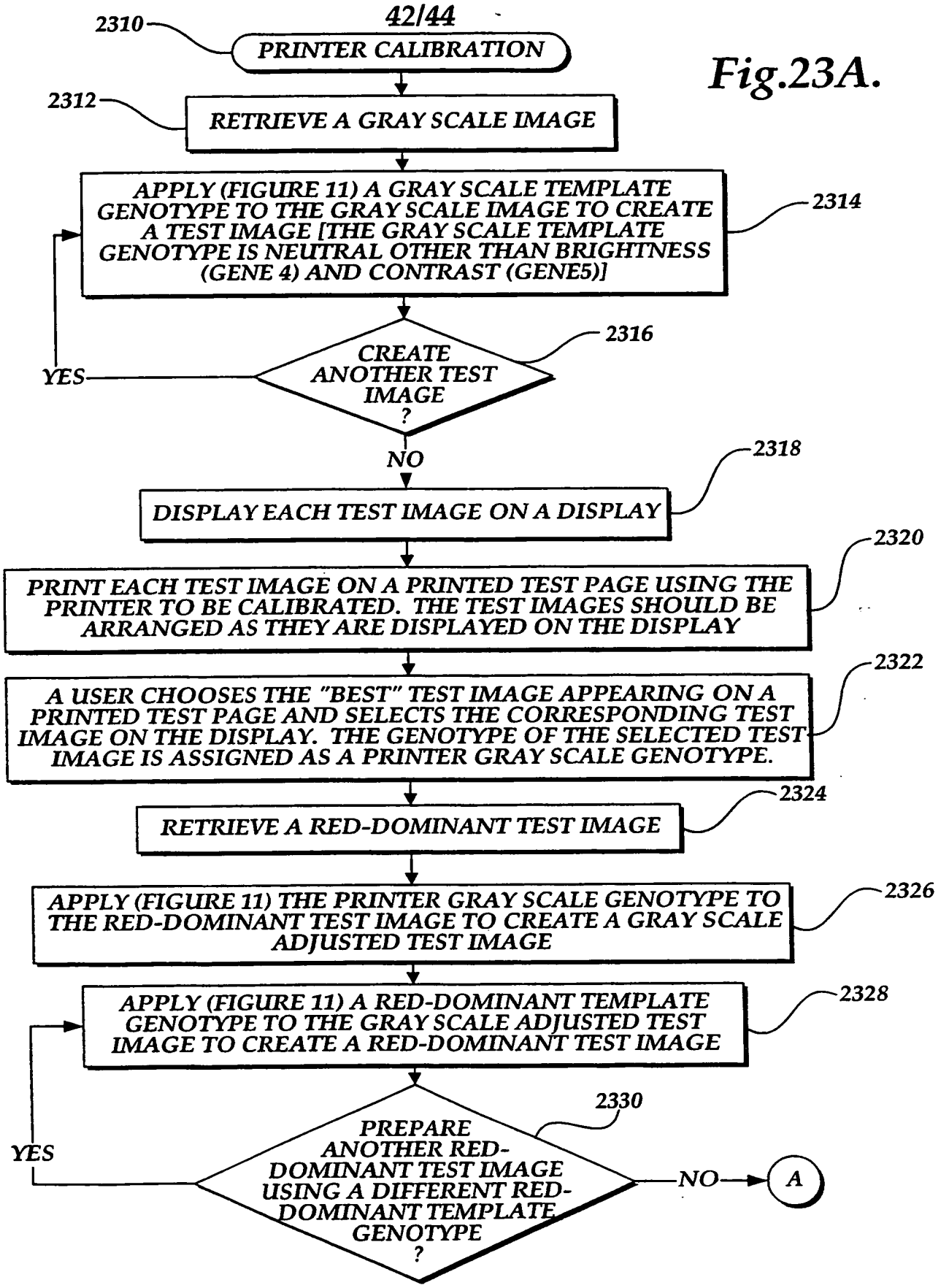

2310
PRINTER CALIBRATION
2312
RETRIEVE A GRAY SCALE IMAGE
APPLY (FIGURE 11) A GRAY SCALE TEMPLATE GENOTYPE TO THE GRAY SCALE IMAGE TO CREATE A TEST IMAGE [THE GRAY SCALE TEMPLATE GENOTYPE IS NEUTRAL OTHER THAN BRIGHTNESS (GENE 4) AND CONTRAST (GENE5)]
2314
CREATE ANOTHER TEST IMAGE ?
2316
YES
NO
DISPLAY EACH TEST IMAGE ON A DISPLAY
2318
PRINT EACH TEST IMAGE ON A PRINTED TEST PAGE USING THE PRINTER TO BE CALIBRATED. THE TEST IMAGES SHOULD BE ARRANGED AS THEY ARE DISPLAYED ON THE DISPLAY
2320
A USER CHOOSES THE "BEST" TEST IMAGE APPEARING ON A PRINTED TEST PAGE AND SELECTS THE CORRESPONDING TEST IMAGE ON THE DISPLAY. THE GENOTYPE OF THE SELECTED TEST IMAGE IS ASSIGNED AS A PRINTER GRAY SCALE GENOTYPE.
2322
RETRIEVE A RED-DOMINANT TEST IMAGE
2324
APPLY (FIGURE 11) THE PRINTER GRAY SCALE GENOTYPE TO THE RED-DOMINANT TEST IMAGE TO CREATE A GRAY SCALE ADJUSTED TEST IMAGE
2326
APPLY (FIGURE 11) A RED-DOMINANT TEMPLATE GENOTYPE TO THE GRAY SCALE ADJUSTED TEST IMAGE TO CREATE A RED-DOMINANT TEST IMAGE
2328
PREPARE ANOTHER RED-DOMINANT TEST IMAGE USING A DIFFERENT RED-DOMINANT TEMPLATE GENOTYPE ?
2330
YES
NO
A

Fig.23A.

Fig.23B.

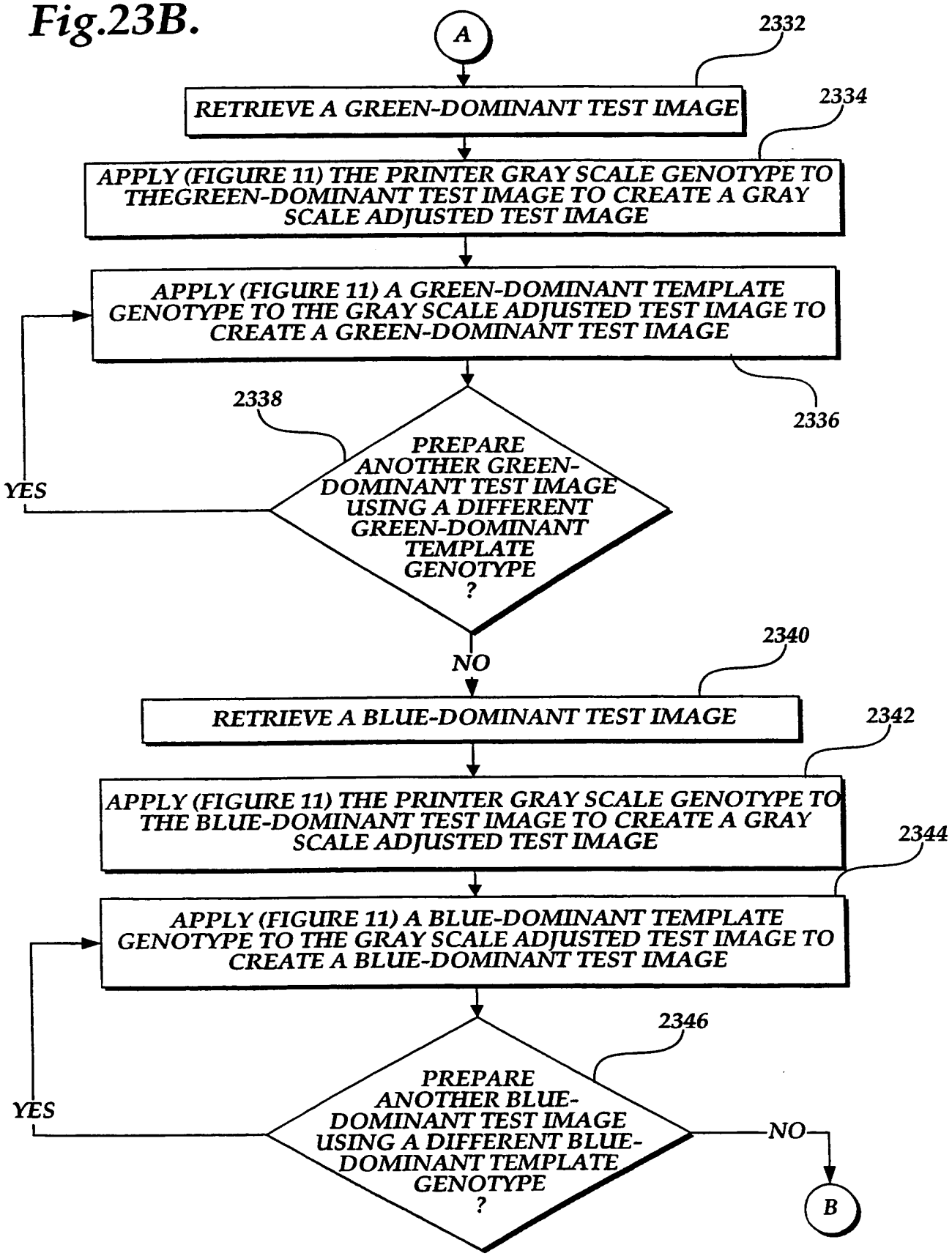
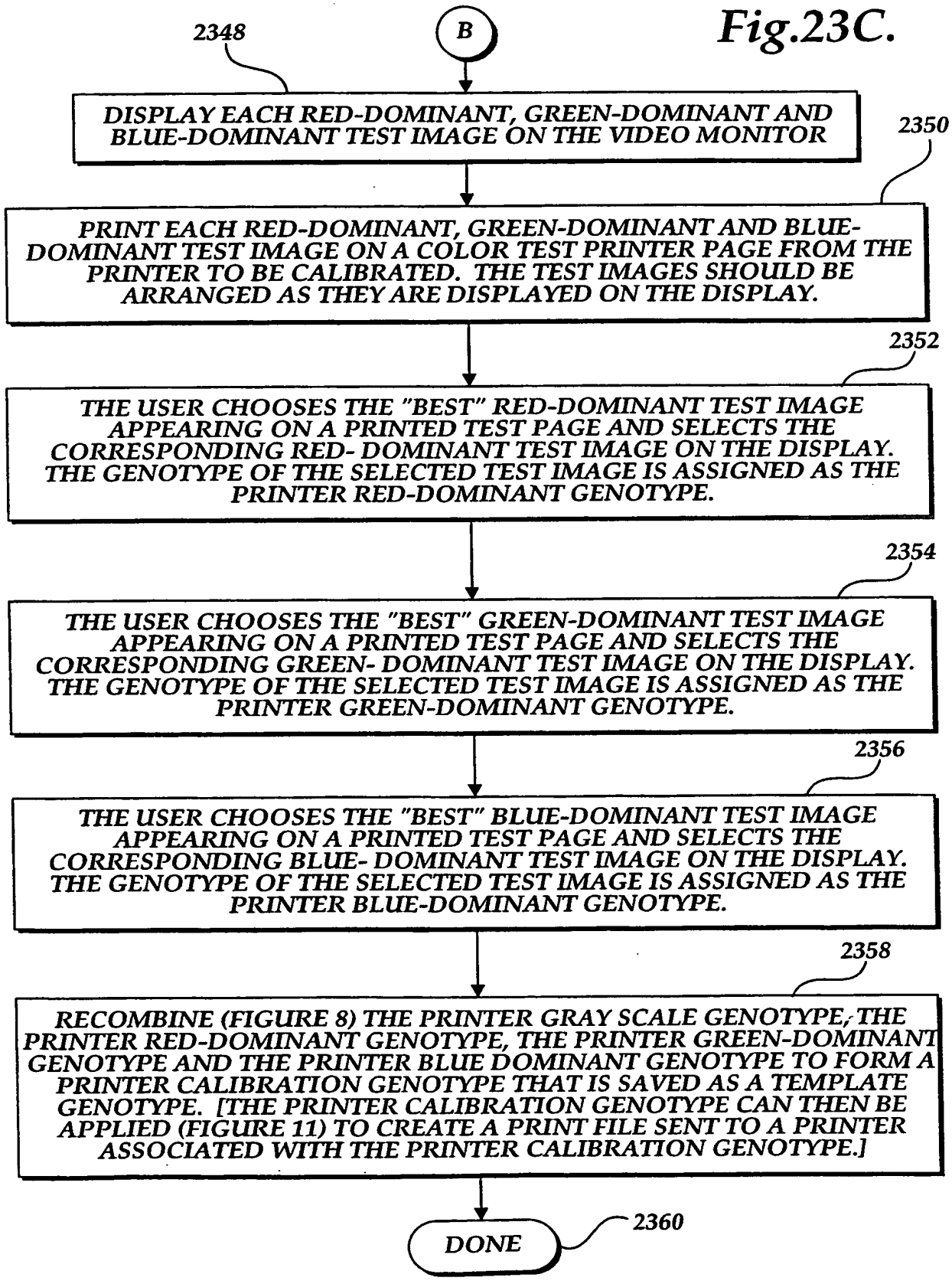

A
2332
RETRIEVE A GREEN-DOMINANT TEST IMAGE
2334
APPLY (FIGURE 11) THE PRINTER GRAY SCALE GENOTYPE TO THEGREEN-DOMINANT TEST IMAGE TO CREATE A GRAY SCALE ADJUSTED TEST IMAGE
APPLY (FIGURE 11) A GREEN-DOMINANT TEMPLATE GENOTYPE TO THE GRAY SCALE ADJUSTED TEST IMAGE TO CREATE A GREEN-DOMINANT TEST IMAGE
2336
2338
PREPARE ANOTHER GREEN-DOMINANT TEST IMAGE USING A DIFFERENT GREEN-DOMINANT TEMPLATE GENOTYPE ?
YES
NO
2340
RETRIEVE A BLUE-DOMINANT TEST IMAGE
2342
APPLY (FIGURE 11) THE PRINTER GRAY SCALE GENOTYPE TO THE BLUE-DOMINANT TEST IMAGE TO CREATE A GRAY SCALE ADJUSTED TEST IMAGE
2344
APPLY (FIGURE 11) A BLUE-DOMINANT TEMPLATE GENOTYPE TO THE GRAY SCALE ADJUSTED TEST IMAGE TO CREATE A BLUE-DOMINANT TEST IMAGE
2346
PREPARE ANOTHER BLUE-DOMINANT TEST IMAGE USING A DIFFERENT BLUE-DOMINANT TEMPLATE GENOTYPE ?
YES
NO
B

Fig.23C.


2348
B
DISPLAY EACH RED-DOMINANT, GREEN-DOMINANT AND BLUE-DOMINANT TEST IMAGE ON THE VIDEO MONITOR
2350
PRINT EACH RED-DOMINANT, GREEN-DOMINANT AND BLUE-DOMINANT TEST IMAGE ON A COLOR TEST PRINTER PAGE FROM THE PRINTER TO BE CALIBRATED. THE TEST IMAGES SHOULD BE ARRANGED AS THEY ARE DISPLAYED ON THE DISPLAY.
2352
THE USER CHOOSES THE "BEST" RED-DOMINANT TEST IMAGE APPEARING ON A PRINTED TEST PAGE AND SELECTS THE CORRESPONDING RED- DOMINANT TEST IMAGE ON THE DISPLAY. THE GENOTYPE OF THE SELECTED TEST IMAGE IS ASSIGNED AS THE PRINTER RED-DOMINANT GENOTYPE.
2354
THE USER CHOOSES THE "BEST" GREEN-DOMINANT TEST IMAGE APPEARING ON A PRINTED TEST PAGE AND SELECTS THE CORRESPONDING GREEN- DOMINANT TEST IMAGE ON THE DISPLAY. THE GENOTYPE OF THE SELECTED TEST IMAGE IS ASSIGNED AS THE PRINTER GREEN-DOMINANT GENOTYPE.
2356
THE USER CHOOSES THE "BEST" BLUE-DOMINANT TEST IMAGE APPEARING ON A PRINTED TEST PAGE AND SELECTS THE CORRESPONDING BLUE- DOMINANT TEST IMAGE ON THE DISPLAY. THE GENOTYPE OF THE SELECTED TEST IMAGE IS ASSIGNED AS THE PRINTER BLUE-DOMINANT GENOTYPE.
2358
RECOMBINE (FIGURE 8) THE PRINTER GRAY SCALE GENOTYPE, THE PRINTER RED-DOMINANT GENOTYPE, THE PRINTER GREEN-DOMINANT GENOTYPE AND THE PRINTER BLUE DOMINANT GENOTYPE TO FORM A PRINTER CALIBRATION GENOTYPE THAT IS SAVED AS A TEMPLATE GENOTYPE. [THE PRINTER CALIBRATION GENOTYPE CAN THEN BE APPLIED (FIGURE 11) TO CREATE A PRINT FILE SENT TO A PRINTER ASSOCIATED WITH THE PRINTER CALIBRATION GENOTYPE.]
DONE
2360

INTERNATIONAL SEARCH REPORT

International application No
PCT/US 99/28676

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F15/18 G06T11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06F G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KARL SIMS: "Artificial Evolution for Computer Graphics" COMPUTER GRAPHICS, vol. 25, no. 4, July 1991 (1991-07), pages 319-328, XP002136078	1-29,36, 47
Y	the whole document	30-35, 37-46
Y	EP 0 714 069 A (MATSUSHITA ELECTRIC IND CO LTD) 29 May 1996 (1996-05-29) abstract; claims 1,14,27-31; figure 70 page 2, paragraph 2	1-29,36, 47
Y	CATHY ABES: "KPT Adds 3-D and Animation to the Mix" MACWORLD,January 1996 (1996-01), page 112 XP002136079 the whole document	1-29,36, 47

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2000	15/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Filloy Garcia, E

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